XI. *On the Tides of the Arctic Seas.*

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Part I. *On the Diurnal Tides of Port Leopold, North Somerset.*

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I AM indebted to the courtesy of Captain WASHINGTON, R.N., Hydrographer to the Navy, for the opportunity I have had of investigating the tides of Port Leopold. Having heard that I was engaged in the discussion of the Arctic Tides, he kindly placed at my disposal the observations made on board Her Majesty's Ship 'Investigator,' during the expedition of 1848–49, under the orders of Sir JAMES C. ROSS, R.N., in search of Sir JOHN FRANKLIN.

The 'Investigator' was anchored, or rather fast in the ice, during the winter of 1848, in Port Leopold, North Somerset, lat. 74° N., long. 90° W., in three fathoms water; and the observations on the tides were made by Lieut. FREDERICK ROBINSON, whose care and skill in observing are highly to be commended.

By carefully laying down the daily high and low waters, I have succeeded in completely separating the Diurnal from the Semidiurnal Tide, and in resolving each tide into the portions due respectively to the action of the Sun and of the Moon.

In the following discussion of the Diurnal Tide, I shall first give the results of the actual observations, when graphically laid down, and afterwards draw the inferences which appear to follow from them, when compared with theory. The mode of reduction used by me will be evident from an inspection of the MS. diagrams which accompany this paper.

The following Table contains the Range of Diurnal Tide at High and at Low Water, and the Times of Vanishing of the Diurnal Tide at High and at Low Water.

TABLE I.—Range and Time of Vanishing of Diurnal Tide at Port Leopold, Prince Regent's Inlet, 1848–49.

Range of Tide.		Time of Vanishing.	
High Water.	Low Water.	High Water.	Low Water.
ft.	ft.		November 1848.
2·16	1·55	November 1848.	$4^d\ 12^h\ 30^m$
2·41	1·20	$21^d\ 9^h\ 15^m$	17 20 0

TABLE I. (continued).

Range of Tide.		Time of Vanishing.	
High Water.	Low Water.	High Water.	Low Water.
ft.	ft.		
2·17	1·22	December 1848.	December 1848.
		6^d 18^h 10^m	2^d 21^h 45^m
2·40	1·57		
		19 18 50	15 18 30
2·31	1·19	January 1849.	December 1848.
		4 2 15	31 16 0
2·40	1·57		January 1849.
		17 9 30	12 23 30
2·05	1·33	February 1849.	
		1 16 55	28 13 0
2·23	1·38		February 1849.
		14 17 0	11 8 40
1·84	0·95		
		27 6 45	27 3 30
1·46*	0·87*	March 1849.	March 1849.
		13 8 30	11 17 15
1·53*	1·07*		
		25 13 15	24 10 20
1·31*	0·84*	April 1849.	April 1849.
		6 2 20	5 17 15
1·55*	0·63*		
		21 11 15	18 3 30
1·96	0·86	May 1849.	
		3 18 15	30 12 50
2·26	0·87	May 1849.	May 1849.
		19 3 15	14 10 19
2·34	1·22		
		31 14 15	27 23 20
2·03	0·97	June 1849.	June 1849.
		16 6 0	11 22 20
2·44	1·35		
		29 5 20	24 17 30
2·14	1·23	July 1849.	July 1849.
		14 12 45	10 18 50
2·27	1·28		
		27 19 30	23 23 20

To render more evident the law of range of Diurnal Tide, I here give in Plate X. figs. I. and II., a graphical representation of the first two columns of the preceding Table, by means of which the relation of the range of Diurnal Tide, at High and Low Water, to the Solstices and Equinoxes is made apparent.

There is no difficulty in understanding, as will be presently shown, why the Diurnal Tide should reach a maximum at the Solstices, and a minimum at the Equinoxes, as is shown by the curves for High and Low Water, because the Solar Diurnal Tide vanishes at the Equinoxes, and consequently the equinoctial Diurnal Tide is due solely to the Moon, while the Solstitial Diurnal Tide is due to the united action of both Sun and Moon.

The following Tables II. and III. show the interval between the vanishing of the Diurnal Tide and the time of the vanishing of the Moon's Declination.

* Transactions of the Royal Irish Academy, vol. xxiii. pp. 133, 134, 137.

TABLE II.—Relation of the Times of Vanishing of the Diurnal Tide at High Water, to the Vanishing of the Moon's Declination.

Date.	Vanishing of Tide.	Interval from Moon's Declination Vanishing.
	d h m	d h
1848. November	21 9 15	+1 6
„ December	6 18 10	+2 3
„ „	19 18 50	+2 6
1849. January	4 2 15	+2 20
„ „	17 9 30	+3 8
„ February	1 16 55	+4 8
„ „	14 17 0	+4 12
„ „	27 6 45	+2 18
„ March	13 8 30	+3 18†
„ „	25 13 15	+1 16†
„ April	6 2 20	+0 6†
„ „	21 11 15	+1 4
„ May	3 18 15	+0 12
„ „	19 3 15	+1 10
„ „	31 14 15	+1 6
„ June	16 6 0	+1 22
„ „	29 5 20	+2 12
„ July	14 12 45	+2 22
„ „	27 19 30	+3 14
	Mean ...	$+2^{d}\ 9^{h}$

In this Table, the positive sign denotes that the Vanishing of the Diurnal Tide followed the Vanishing of the Moon's Declination.

TABLE III.—Relation of the Times of Vanishing of the Diurnal Tide at Low Water, to the Vanishing of the Moon's Declination.

Date.	Vanishing of Tide.	Interval from Moon's Declination Vanishing.
	d h m	d h
1848. November	4 12 30	−3 3
„ „	17 20 0	−1 21
„ December	2 21 45	−1 14
„ „	15 18 30	−1 12
„ „	31 16 0	−0 21
1849. January	12 23 30	−0 18
„ „	28 13 0	+0 9
„ February	11 8 40	+0 16
„ „	27 3 30	+2 15
„ March	11 17 15	+2 4†
„ „	24 10 20	+0 14†
„ April	5 17 15	−0 4†
„ „	18 3 30	−2 3
„ „	30 12 50	−2 22
„ May	14 10 19	−2 15
„ „	27 23 20	−2 11
„ June	11 22 20	−2 4
„ „	24 17 30	−2 2
„ July	10 18 50	−0 18
„ „	23 23 20	−0 4
	Mean ...	$-0^{d}\ 22^{h}\ 30^{m}$

In this Table, the positive sign denotes that the Vanishing of the Diurnal Tide follows the Vanishing of the Moon's Declination, and the negative sign denotes that it precedes it. From the mean result of the two Tables, it would seem that the Vanishing of the Diurnal Tide at Low Water *precedes* the Vanishing of the Diurnal Tide at High Water, by a mean amount of $3^{d}\ 7^{h}\ 30^{m}$.

The intervals at which the vanishing of the Diurnal Tide at High Water follows the Vanishing at Low Water are shown in detail in the following Table and in fig. III., Plate XI.

TABLE IV.—Intervals from the Vanishing of the Diurnal Tide at Low Water to Vanishing of Diurnal Tide at High Water.

Date.	Intervals.
	d h m
1848. November	3 13 15
„ December	3 20 25
„ „	4 0 20
„ „	3 10 15
1849. January	4 10 0
„ „	4 3 55
„ February	3 8 20
„ „	0 3 15
„ March	1 15 15
„ „	1 2 55
„ April	0 9 5
„ „	3 7 45
„ „	3 5 25
„ May..............	4 16 56
„ „	3 14 55
„ June..............	4 7 40
„ „	4 11 50
„ July	3 17 55
„ „	3 20 10
Mean ...	$3^{d}\ 5^{h}\ 27^{m}$

From the foregoing Table it is evident that the interval between the vanishing of the Diurnal Tide at the time of High and of Low Water, increases from the Equinoxes to the Solstices—an effect which is in a great degree due to the Solar Tide, which disappears at the Equinoxes and reaches a maximum at the Solstices. The regularity with which this increase of interval takes place is still better shown by the figure, which represents the Table, the abscissæ denoting time, and the ordinates the interval from the vanishing of the Diurnal Tide at Low Water to its vanishing at High Water. The minimum interval, 12 hours, occurs at the time of the Equinoxes, and the maximum interval, 4 days to $4\frac{1}{4}$ days, occurs at the time of the Solstices.

I am not aware that this feature of the Diurnal Tide has been before noticed; it is perfectly in accordance with what might be expected from Tidal Theory.

According to the best theories of the Tides, the Diurnal Tide may be represented by the expression

$$D = S \sin 2\bar{\sigma} \cos(s - i_s) + M \sin 2\bar{\mu} \cos(m - i_m) . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

In this equation

D is the height of the Diurnal Tide, in feet.

S and M are the coefficients, in feet, of the Solar and Lunar Diurnal Tides.

$\bar{\sigma}$ and $\bar{\mu}$ are the Declinations of the Sun and Moon, at a period preceding the moment of observation, by an unknown interval to be determined for each luminary, and called the Age of the Solar and Lunar Diurnal Tide.

s and m are the hour-angles of the Sun and Moon, west of the meridian, at the time of observation.

i_s and i_m are the Diurnal Solitidal and Lunitidal intervals, or the times which elapse between the Sun and Moon's southing, and the time of Solar and Lunar Diurnal High Water.

At any time near the Equinox, the declination $\bar{\sigma}$ of the Sun is either zero or very small, and therefore D will vanish when $\bar{\mu}$, the Moon's declination, vanishes, and this will happen at both High and Low Water, or at any other time of the day; therefore at the equinoxes the vanishing of the diurnal tide at the time of High or of Low Water ought to be sensibly the same; but at the time of the Solstices, both members of the right-hand side of equation (1.) will have sensible values, and the Diurnal Tide will vanish when these members are equal and of opposite signs; therefore, to find the time of vanishing of the Diurnal Tide, we have

$$\cos(s-i_s)=-\frac{M}{S}\cdot\frac{\sin 2\bar{\mu}\cos(m-i_m)}{\sin 2\bar{\sigma}}. \quad \ldots \ldots \ldots \quad (2.)$$

At the time of High Water, m, the moon's hour-angle is sensibly constant, or at least varies within narrow limits; also, since the vanishing of the Diurnal Tide at High Water occurs at intervals of about a semilunation, the moon's declination, $\bar{\mu}$, at each vanishing of the Diurnal Tide will also vary within small limits; hence in passing from the equinox to the solstice, the right-hand side of (2.) will have its change of value depending chiefly on the change of $\bar{\sigma}$; and it will therefore diminish as $\bar{\sigma}$ increases; therefore $\cos(s-i_s)$ will diminish, and $(s-i_s)$ *increase*; but s is the hour-angle of the Sun at the time of High Water, and increases day by day (48^m mean); therefore as we approach the Solstice, the day on which we are to expect the Diurnal Tide to vanish at the time of High Water will occur later and later.

But at the time of Low Water the angles s and m must be increased by 90° or 6 hours; and therefore (2.) becomes

$$\sin(s-i_s)=-\frac{M}{S}\cdot\frac{\sin 2\bar{\mu}\sin(m-i_m)}{\sin 2\bar{\sigma}}. \quad \ldots \ldots \ldots \quad (3.)$$

By reasoning similar to that used with respect to equation (2.), we can show that $\sin(s-i_s)$ diminishes in passing from the Equinox to the Solstice, and therefore that $(s-i_s)$ also *diminishes*; therefore the time of vanishing of the Diurnal Tide at the time of Low Water occurs earlier and earlier as we approach the Solstice. We thus see that the times of vanishing at High and Low Water move in opposite directions, and

become most widely separated at the time of the Solstice. This result agrees perfectly with the facts of observation at Port Leopold recorded in Table IV. and the accompanying fig. III. Plate XI.

I shall now endeavour to separate, in the Diurnal Tide, the effects of the Sun and Moon. In equation (1.), the effect of the Sun, represented by the first member of the right-hand side of the equation, when observed at High Water, may be considered to owe its periodical change almost altogether to the change in $\cos(s-i_s)$, the angle s increasing day by day as the tide becomes later and later; for the angle $\bar{\sigma}$ may be regarded as sensibly constant during the semilunation. On the other hand, the Lunar portion of the Diurnal Tide owes its change to the change of $\bar{\mu}$, the moon's declination, for the angle $(m-i_m)$ is sensibly constant. The Solar Diurnal Tide disappears at the equinox, because then $\bar{\sigma}=0$; hence we may find the Lunar Diurnal Tide, at that period of the year, uncomplicated by the coexistence of the Solar Tide.

Taking the means of the Diurnal Tide Ranges at High and Low Water for March and April*, I find

At High Water

$$D=1{\cdot}462 \text{ ft.}=M\sin(2\bar{\mu}).\cos(m-i_m);$$

at Low Water

$$D=0{\cdot}852 \text{ ft.}=M\sin(2\bar{\mu}).\cos(m-i_m+90°),$$

m denoting the moon's hour-angle at High Water, and $\bar{\mu}$ denoting the moon's maximum declination. Dividing one of these equations by the other, we find

$$\cot(m-i_m)=-\frac{1{\cdot}462}{0{\cdot}852}; \quad \ldots\ldots\ldots\ldots \quad (4.)$$

from which we deduce

$$m-i_m=149°\ 46'=10^h\ 19^m.$$

m, the moon's hour-angle at High Water, is shown by the observations made in March and April to have at New and Full Moon a mean value of $12^h\ 0^m$. Substituting this value in the preceding equation, I obtain,

(1) *The Lunitidal Diurnal Interval* $=i_m=1^h\ 41^m$.

The coefficient M of the Lunar Diurnal Tide may be found as follows:—

Let H=Range of Diurnal Tide, at High Water, at the equinox.

Let L=Range of Diurnal Tide, at Low Water, at the equinox.

Then

$$2M\sin 2(\text{max. declination of moon})=\sqrt{H^2+L^2}. \quad \ldots\ldots \quad (5.)$$

Substituting in this equation the values of H, L, and $\bar{\mu}$, we find

$$2M\sin 37°=\sqrt{(1{\cdot}462)^2+(0{\cdot}852)^2}=1{\cdot}692 \text{ feet};$$

* The Tide Ranges used in obtaining these means and marked (*) in Table I.

and therefore, finally,

(2) *Coefficient of Lunar Diurnal Tide* $=\mathrm{M}=1{\cdot}409$ feet.

The Age of the Lunar Diurnal Tide is found by examining the interval, at the Equinox, from the vanishing of the Moon's declination to the vanishing of the Diurnal Tide, at High and at Low Water. The interval from the Moon's declination vanishing to the Tide vanishing is given in Tables II. and III. for High and Low Water; and the figs. IV. and V. of Plate XI. represent the results of those Tables.

From these figures, or from the Tables which they represent, it is evident that the difference in the time of vanishing of the Diurnal Tide at the times of High and Low Water is not altogether due to the Solar Tide; for at the Equinox, when the Solar Tide has disappeared, the Age of the Lunar Diurnal Tide at High Water is $1^d\ 21^h$, while the Age of the same Tide at Low Water is only $0^d\ 21^h$; showing a permanent difference of one whole day in the times of disappearance of the Tide at High and Low Water quite independent of the Solar Tide, which, as I have already shown, tends to increase this difference as we approach the Solstices.

The Means of the Ages of the Diurnal Tide, taken from the Tides of the 13th and 25th of March and the 6th of April, 1849, at High Water, and from the Tides of the 11th and 24th of March and the 5th of April, 1849, at Low Water, are $1^d 21^h$ and $0^d 21^h$*.

I am unable to explain why the Age of the Lunar Diurnal Tide at High Water should be greater than its Age at Low Water; but there is good reason to believe that it is an established fact, as I found the same kind of difference of Age in the Tidal Observations made in 1850–51, on the coasts of Ireland, by the Royal Irish Academy. The following Table shows the difference in the Irish stations.

Age of Lunar Diurnal Tide, deduced from Observations at High and Low Water, on the Coasts of Ireland, 1850–51 (from Transactions of the Royal Irish Academy, vol. xxiii. p. 137).

Station.	Age at High Water.	Age at Low Water.	Difference.
	d h	d h	d h
Caherciveen	5 4	4 17	0 11
Bunown	4 9	4 9	0 0
Rathmullan	5 10	4 20	0 14
Portrush	5 9	4 19	0 14
Cushendall	6 19	5 3	1 16
Donaghadee	6 5	5 2	1 3
Kingstown	6 17	4 11	2 6
Courtown	6 22	3 12	3 10
Dunmore East	5 19	5 14	0 5
Means	$5^d\ 20^h\ 40^m$	$4^d\ 17^h\ 13^m$	$1^d\ 3^h\ 27^m$

Bringing together the Constants of the Lunar Diurnal Tide just determined, they are as follow:—

* These tides are marked (†) in Tables II. and III.

1. Diurnal Lunitidal Interval . . . . $1^h\ 41^m$
2. Age of Lunar Diurnal Tide at High Water . $1^d\ 21^h$
   ,, ,, Low Water . $0^d\ 21^h$
3. Coefficient of Lunar Diurnal Tide . . . . 1·409 ft.

It remains now to determine, if possible, the corresponding Constants of the Solar Diurnal Tide. In order to effect this object, I laid down the Lunar Tide, both at High and Low Water, from the preceding constants, on the observed Diurnal Tide at the time of the Solstices, and thus obtained the constants of the Solar Tide, which at those periods of the year is a maximum.

Having thus constructed the Lunar Tide, I found, by the difference between it and the Observed Diurnal Tide, that the maximum Solar Diurnal Tide was as follows:—

	ft.
Range of Solidiurnal Tide at High Water:—	
Summer Solstice, 1849	0·82
Winter Solstice, 1848	0·91
Range of Solidiurnal Tide at Low Water:—	
Summer Solstice, 1849	0·86
Winter Solstice, 1848	0·88
Mean . . .	0·867 ft.

The following Table shows the time at which the Solar Diurnal Tide vanished at the Solstices.

Vanishing of Solar Diurnal Tide at High Water.

	h m		h m
Summer Solstice, 1849. Tide passing from — to +.		Summer Solstice, 1849. Tide passing from + to —.	
May 31	8 34	June 16	20 10
June 29	8 20	July 14	18 50
Winter Solstice, 1848. Tide passing from + to —.		Winter Solstice, 1848. Tide passing from — to +.	
Dec. 19	8 15	Dec. 6	20 50
Jan. 17	8 35	Jan. 4	20 10
Mean	$8^h\ 26^m$	Mean	$20^h\ 0^m$

Vanishing of Solar Diurnal Tide at Low Water.

	h m		h m
Summer Solstice, 1849. Tide passing from — to +.		Summer Solstice, 1849. Tide passing from + to —.	
June 23	7 30	June 19	19 45
July 23	8 19	July 8	19 48
Winter Solstice, 1848. Tide passing from + to —.		Winter Solstice, 1848. Tide passing from — to +.	
Dec. 28	7 30	Dec. 13	19 40
Jan. 27	8 30	Jan. 12	20 0
Mean	$7^h\ 57^m$	Mean	$19^h\ 48^m$

It will be observed in the preceding Table, that the time of the Diurnal Solar Tide vanishing may be referred to one or other of two hours, which differ by 12^h, and that the times of passing from + to − at the two solstices are reversed. These changes are evident from the consideration of the expression for the Solar Diurnal Tide,

$$S \sin 2\bar{\sigma} . \cos(s-i_s),$$

which changes sign, from Solstice to Solstice, by the change of sign of $(\bar{\sigma})$, the sun's declination, and also changes sign at the two high waters or low waters of the same day by the increment of 180° which the sun's hour-angle s undergoes. Combining all the results together, I find that the Solar Diurnal Tide vanishes at High Water when

$$8^h\ 26^m - i_s = 18^h,$$

and

$$20^h \quad - i_s = 6^h,$$

or

$$i_s = -9^h\ 34^m, \text{ and } +14^h.$$

$$\text{Mean value of } i_s = 14^h\ 13^m;$$

and that the Solar Diurnal Tide vanishes at Low Water when

$$7^h\ 57^m - i_s = 18^h,$$

and

$$19^h\ 48^m - i_s = 6^h,$$

or

$$i_s = -10^h\ 3^m, \text{ and } +13^h\ 48^m.$$

$$\text{Mean value of } i_s = 13^h\ 52^m\ 30^s.$$

The Mean of the values of the Solitidal Interval, at High and Low Water, is

$$i_s = 14^h\ 2^m\ 45^s.$$

From the preceding data we can readily find the coefficient of the Solar Diurnal Tide; for

$$S \times \sin(\text{max. declination of Sun}) = 0{\cdot}867 \text{ feet},$$

or

$$S = \frac{0{\cdot}867}{\sin(47°)} = 1{\cdot}186 \text{ feet}.$$

The Age of the Solar Diurnal Tide cannot be deduced from observations such as those under discussion, because the Sun's declination changes so slowly at the Solstices, that it may be considered constant during a fortnight, and therefore the Coefficient $S \sin(2\bar{\sigma})$ is also constant during that period. The Constants of the Solar Diurnal Tide, as just found, are as follow:—

1. Diurnal Solitidal Interval . . . $14^h\ 2^m\ 45^s$.
2. Age of Solar Diurnal Tide . . . Unknown.
3. Coefficient of Solar Diurnal Tide . 1·186 feet.

The ratio of the Solar to the Lunar Coefficient is

$$\frac{S}{M} = \frac{1{\cdot}186}{1{\cdot}409} = 0{\cdot}842.$$

This result differs widely from the ratios of S to M found by me at the Irish Stations, which were as follow:—

Ratio of the Solar to the Lunar Coefficient of the Diurnal Tide, on the Coasts of Ireland, 1850–51 (from Trans. Roy. Irish Acad. vol. xxiii. p. 128).

Station.	$\frac{S}{M}$.
Caherciveen	0·698
Bunown	0·529
Rathmullan	0·498
Portrush	0·659
Cushendall	0·427
Donaghadee	0·441
Kingstown	0·504
Courtown	0·570
Dunmore East	0·436
Mean	0·5305

I shall now deduce, according to received theories, the mean depth of the channel of the Atlantic Sea, which conveys the tide from the South Atlantic Ocean to Port Leopold. The theory which I select for this purpose is that given by Mr. AIRY in his 'Tides and Waves,' which is considerably in advance of that given by LAPLACE and the earlier mathematicians, and, as it is directly founded on the motion of water in canals, seems particularly well adapted to the discussion of a tide like that of Port Leopold, which is situated at the extreme northern end of the Atlantic Ocean, which may be regarded as a Canal occupying a meridian circle, and nearly 10,000 miles in length. From the discussion of the Diurnal Tide, in a meridian canal, given by Mr. AIRY (Tides and Waves, p. 356), it may be deduced that the following equation is true, and that it contains the means of finding the mean depth of the Atlantic Canal:

$$\frac{S}{M}=\frac{\text{mass of Sun}}{\text{mass of Moon}}\times\frac{d^3}{D^3}\times\frac{\frac{n^2b}{g}-4\frac{k}{b}}{\frac{N^2b}{g}-4\frac{k}{b}}. \quad \text{(6)}$$

In this equation,

S, M are the coefficients of the Solar and Lunar Diurnal Tide, found, as at Port Leopold, by observation.

D, d are the mean distances of the Sun and Moon from the Earth.

N, n are the angular velocities of the Sun and Moon about the Earth.

b is the mean radius of the Earth.

k is the mean depth of the Atlantic Canal.

g is the velocity acquired in a second by a falling body.

The left-hand side of equation (6.) is known by observation, and all the quantities on the right-hand side are known, except k.

Substituting, therefore, for the symbols the following values,

$$\frac{S}{M}=0\cdot842,$$

$$\frac{\text{mass of Sun}}{\text{mass of Moon}}=359551\times 85,$$

$$\frac{d}{D}=\frac{59\cdot964}{2\times 12032},$$

$$\frac{\text{mass of Sun}}{\text{mass of Moon}}\times\frac{d^3}{D^3}=0\cdot47288;$$

$$b=\frac{7912}{2}\text{ miles};$$

$$\frac{N^2b}{g}=0\cdot00345;$$

$$\frac{n^2b}{g}=0\cdot00323;$$

we find

$$0\cdot842=0\cdot473\,\frac{0\cdot00323-4\dfrac{k}{b}}{0\cdot00345-4\dfrac{k}{b}};$$

from which I deduce

$$\frac{k}{b}=\frac{1}{1072},\quad k=3\cdot69\text{ miles}.$$

In discussing the Solar and Lunar Diurnal Tides of nine stations on the Irish Coasts, I found the following results*:—

$$\frac{S}{M}\text{ (mean of nine Stations)}=0\cdot5305;$$

$$\frac{k}{b}=\frac{1}{773};\quad k=5\cdot12\text{ miles}.$$

The mean depth of the Atlantic Canal may be also deduced, by means of Mr. AIRY's Theory of Tides with Friction, from a comparison of the Solitidal and Lunitidal Intervals, and from the Lunitidal Interval compared with the Age of the Lunar Tide.

According to the Theory of Tidal Waves without Friction, Low Water should occur at the time of the meridian passage of the luminary; in consequence, however, of friction, the phase of High Water is accelerated by an interval equal to the difference between the Tidal Interval and half the period of a Tidal Oscillation. According to Mr. AIRY's Theory, taking account of friction (supposed proportional to the horizontal velocity of the tidal current), the acceleration of High Water is represented by†

$$\frac{f}{n^2-gkm^2};$$

* Trans. Royal Irish Academy, vol. xxiii. pp. 128, 131.

† Tides and Waves, p. 332.

where

f=coefficient of friction;
n=angular velocity of Luminary;
g=32 feet;
k=depth of the sea;

$$m=\frac{2\pi}{\lambda};$$

λ=length of the tide-wave.

Therefore

$$\frac{\text{Lunitidal Acceleration}}{\text{Solitidal Acceleration}}=\frac{N^2-gkm^2}{n^2-gkm^2}; \quad \ldots \ldots \quad (7.)$$

and, substituting the following values,

$$n=\frac{2\pi}{89280}, \quad N=\frac{2\pi}{86400},$$

$$m=\frac{2\pi}{25000\times 5280};$$

we find, k being expressed in miles,

$$\frac{\text{Acceleration of Lunar Diurnal Tide}}{\text{Acceleration of Solar Diurnal Tide}}=\frac{13{\cdot}815-k}{12{\cdot}938-k}. \quad \ldots \ldots \quad (8.)$$

To find the Lunitidal and Solitidal Accelerations, we must subtract the Lunitidal and Solitidal Intervals, i_m and i_s, from $12^h\ 24^m$ and 12^h, respectively; but

$$i_m=\ 1^h\ 41^m,$$
$$i_s=13^h\ 52^m{\cdot}5;$$

therefore

Acceleration of Lunar Diurnal Tide $=+10^h\ 43^m$,
Acceleration (*Retardation*) of Solar Diurnal Tide $=-\ 1^h\ 52^m{\cdot}5$.

Substituting these values in equation (8.), I find

$$k=13{\cdot}07 \text{ miles}.$$

Again, according to Mr. AIRY's Theory of Tidal Waves with friction*, the greatest tide follows the greatest force by an interval (Age of Tide),

$$\frac{f(n^2+gkm^2)}{(n^2-gkm^2)^2};$$

but the acceleration of the Tide is

$$\frac{f}{n^2-gkm^2}.$$

Therefore

$$\frac{\text{Age of Lunidiurnal Tide}}{\text{Acceleration of Lunidiurnal Tide}}=\frac{n^2+gkm^2}{n^2-gkm^2}; \quad \ldots \ldots \quad (9.)$$

or

$$\frac{\text{Age of Lunidiurnal Tide}}{\text{Acceleration of Lunidiurnal Tide}}=\frac{12{\cdot}938+k}{12{\cdot}938-k}. \quad \ldots \ldots \quad (10.)$$

* Tides and Waves, p. 333.

In applying this equation to determine the depth of the sea, the difficulty already noticed, as to the Age of the Lunar Tide, deduced from High Water and Low Water observations, meets us again. The Age at High Water is $1^d\ 21^h$, and at Low Water $0^d\ 21^h$.

Substituting these values respectively, I find

	miles.
Depth of sea (k) deduced from Age of Lunar Diurnal Tide at High Water	=7·96
Depth of sea deduced from Age of Lunar Diurnal Tide at Low Water	=4·19
Mean	=6·07

Bringing together all the preceding results, we find the following mean depths of the Atlantic Canal, as deduced by the various methods described:—

	miles.
1. Depth deduced from Heights of Solar and Lunar Diurnal Tides .	3·69
2. Depth deduced from Accelerations of Solar and Lunar Diurnal Tides, caused by friction	13·07
3. Depth deduced from Acceleration and Age of Lunar Diurnal Tide, caused by friction	6·07

Of the three methods just given for finding the mean depth of the sea, the first is the most trustworthy, for the following reasons:—

1st. The determination of Heights of the Solar and Lunar Diurnal Tide by observation is more accurate than the determination of Acceleration and Age.

2nd. The theory by which the depth of the sea is deduced from Heights is independent of friction, the introduction of which requires additional hypotheses, which are, at best, of a doubtful character.

At the same time it should be remarked that the depth of the sea deduced from Acceleration and Age, at eight stations on the coasts of Ireland, exceeded the depth deduced from Heights, in a manner similar to that which is found to occur at Port Leopold.

The Irish depths are—

	miles.
1. Depth of sea deduced from Heights of Solar and Lunar Diurnal Tides	5·12
2. Depth deduced from Accelerations of Solar and Lunar Diurnal Tides, caused by friction	11·98
3. Depth deduced from Acceleration and Age of the Lunar Diurnal Tide	11·32

In the present state of our knowledge of the Theory of the Tides, I think it is safer to adopt the results deduced from Heights as the most reliable, and to wait until mathematical researches shall have further perfected the Theory of friction in Tidal Waves, before we draw conclusions from it as to the depth of the sea, especially when we consider that this Theory has not yet explained the anomaly discovered by observation as to the difference in Age of the Diurnal Tides deduced from High and Low Waters.

PART II.—*The Semidiurnal Tides of Port Leopold, North Somerset.*

Received October 8,—Read November 27, 1862.

When the daily height of High and Low Water has been cleared of the Diurnal Tide, as explained in Part I., and as is shown in the MS. diagrams that accompany this paper, it is easy to estimate the successive Heights of Spring and Neap Tides, cleared of the Diurnal Tide.

Bringing together the Spring Tides and the Neap Tides, the following Tables I. and II. are constructed; and from the second column of these Tables the diagram No. 1 Plate XII. is prepared, of which the following explanation may be useful.

The interval in the abscissæ corresponds to five Lunar weeks, or intervals between the greatest Spring Tide and least Neap Tide. The ordinates are divided, as usual, into feet.

The Curve a, drawn through alternate Spring Tide Heights, is the curve of New Moon Springs.

The Curve a' is the Curve of Full Moon Springs.

The Curve b is the Curve of First Quarter Neap Tides.

The Curve b' is the Curve of Third Quarter Neaps.

These Curves are constructed from Tables I. and II., which are themselves formed from the Curves of the MS. diagram.

The diagram No. 2, Plate XII. is formed from the first column of Table I. Its abscissæ are the same as those of diagram No. 1, and its ordinates are the Solar Hours at which the Maximum Spring Tide occurred.

Curve a represents the Time of New Moon Springs.

Curve a' the Time of Full Moon Springs.

TABLE I.—Semidiurnal Maximum Spring Tide Ranges, 1848–49.

	Time.	Range.	Moon's Hour-Angle.
	d h m	ft.	h m
1848. October	28 0 30	5·42	1 0
„ November	12 1 0	6·67	1 48
„ „	27 0 45	5·01	1 8
„ December	12 1 0	6·42	2 29
„ „	27 1 15	5·03	1 31
1849. January	10 0 50	6·56	2 4
„ „	26 1 15	5·65	1 54
„ February.........	9 1 0	6·28	2 21
„ „	25 1 45	6·50	2 17
„ March	10 1 0	6·11	1 45
„ „	26 1 30	6·63	1 53
„ April	7 0 30	5·76	2 24
„ „	25 1 20	6·60	2 32
„ May..............	7 0 30	5·50	2 35
„ „	24 1 15	6·47	2 17
„ June..............	8 1 30	4·60	2 28
„ „	21 0 30	6·28	1 0
„ July	8 1 30	5·06	2 48
„ „	22 1 15	6·46	2 33
Mean ...	$1^h\ 4^m$	......	$2^h\ 2^m$

TABLE II.—Semidiurnal Minimum Neap Ranges, 1848–49.

	Sun's Hour-Angle.	Range.	Moon's Hour-Angle.
	d h m	ft.	h m
1848. November	4 5 30	2·33	6 38
,, ,, ...	18 5 45	2·83	7 23
,, December	4 6 0	2·95	7 0
,, ,, ...	18 6 20	2·89	7 32
1849. January	2 6 0	3·55	6 36
,, ,, ...	17 6 30	2·54	7 40
,, February.........	2 7 0	3·65	8 8
,, ,, ...	17 7 30	1·98	8 40
,, March	3 6 45	3·25	7 58
,, ,, ...	18 6 45	2·00	8 8
,, April	1 7 0	3·42	7 46
,, ,, ...	16 6 30	2·27	7 37
,, May...............	1 7 30	3·18	8 17
,, ,, ...	16 7 30	2·76	7 54
,, ,, ...	30 7 45	3·38	8 33
,, June...............	15 6 30	3·14	8 16
,, ,, ...	29 8 0	3·15	7 59
,, July...............	14 7 0	3·27	7 53
,, ,, ...	29 8 10	2·68	8 11
Mean ...	6^h 50^m	......	7^h 48^m

A.—*Parallactic Inequality of Semidiurnal Tide.*

The general expression for the Semidiurnal Tides is, as is well known,

$$T=S\left(\frac{P}{P_m}\right)^3\cos^2\bar{\sigma}\cos 2\,(s-i_s)+M\left(\frac{p}{p_m}\right)^3\cos^2\bar{\mu}\cos 2\,(m-i_m), \quad . \quad . \quad . \quad . \quad (1.)$$

where

S and M are the Solar and Lunar Coefficients;

P and p the Solar and Lunar parallax; and P_m, p_m the mean values of the same.

$\bar{\sigma}$, $\bar{\mu}$ the declinations of the Sun and Moon, at periods preceding that of observation by unknown intervals called the Solar and Lunar Age of the Semidiurnal Tide.

s, m the hour-angles of the Sun and Moon, west of the meridian at the time of observation.

i_s, i_m the Solar and Lunar Tidal intervals, or time after southing of the luminary, at which its high water is found to occur.

From an inspection of diagrams 1 and 2, Plate XII., it is plain that the conditions of the tide are different at New and Full Moon, and in the 1st and 3rd Quarter. But the Solar conditions may be supposed constant for a fortnight, and as the moon's declination only enters equation (1.) by the square of the cosine, it must be *q. p.* the same at the beginning and end of a Lunar fortnight. The difference, therefore, shown in the diagrams must depend on the Moon's Parallax, which takes four weeks to complete its changes.

From diagram No. 1, it appears that the greatest difference in the Parallactic Tide, between the opposite quarters of the Moon, both at Spring and Neap Tides, amounts to 1·47 ft. in the range of the Tide.

I shall presently prove that the Lunar Tide Range at the time of this maximum Parallactic inequality is 4·62 ft.; adding, to this, half the Parallactic inequality, and subtracting it from it, we find

$$\frac{5{\cdot}35}{3{\cdot}89}=\left(\frac{1+e}{1-e}\right)^3, \quad \ldots \ldots \quad (2.)$$

that is, the cube of the ratio of the Apogee to the Perigee. Solving this equation for e, the eccentricity of the moon's orbit, we obtain

$$e=\frac{112}{2112}=0{\cdot}05303. \quad \ldots \ldots \quad (3.)$$

This value of the eccentricity of the moon's orbit is very near the true value 0·05484*, as near, indeed, as could be expected from any Tidal Observations.

B.—*Solar Semidiurnal Tide.*

In diagram No. 1 the Curves marked A and B are drawn so as to eliminate the Parallactic inequality, and they represent the Curves of Spring and Neap Tide Ranges; but from the expression (1) it appears that if we could find two sets of tides, for which the moon's declination and hour-angle should be the same, we could eliminate the Lunar Tide and calculate the Solar Tide separately.

These conditions are fulfilled by the Solstitial Springs and Equinoctial Neaps—as may be thus shown.

Solstitial Springs:—

New Moon	June $20^d\ 2^h\ 19^m$ (Greenwich).
Declination	18° 49′ N. *q. p.* maximum.

Equinoctial Neaps:—

First Quarter	March $30^d\ 18^h\ 58^m$ (Greenwich).
Declination	18° 27′ N. *q. p.* maximum.

And the Curve of Spring Tide Range, cleared of Parallax, attains its Solstitial Minimum, June $21^d\ 12^h\ 40^m$ H.W., and its Equinoctial Maximum, April $1^d\ 12^h\ 20^m$ L.W.

We may therefore safely assume the part of equation (1.) which depends on the Moon to be the same at both these times.

We therefore have

$$\left.\begin{aligned} a' &=2\mathrm{S}\,.\cos^2\overline{\sigma'}\cos 2(s'-i_s)+2\mathrm{M}\cos^2\overline{\mu'}\cos 2(m'-i_m),\\ a_{\prime\prime}&=2\mathrm{S}\,.\cos^2\overline{\sigma_{\prime\prime}}\cos 2(s_{\prime\prime}-i_s)+2\mathrm{M}\cos^2\overline{\mu_{\prime\prime}}\cos 2(m_{\prime\prime}-i_m),\end{aligned}\right\} \quad \ldots \quad (4.)$$

where

a', $\overline{\sigma'}$, s', $\overline{\mu'}$, m' refer to Solstitial Springs,

a' being the Solstitial Spring Range; and

$a_{\prime\prime}$, $\overline{\sigma_{\prime\prime}}$, $s_{\prime\prime}$, $\overline{\mu_{\prime\prime}}$, $m_{\prime\prime}$ refer to Equinoctial Neaps,

$a_{\prime\prime}$ being the Equinoctial Neap Range.

But

$$a'=5{\cdot}56 \text{ ft.}$$
$$a_{\prime\prime}=2{\cdot}67 \text{ ft.}$$

* HERSCHEL's Astronomy, London, 1850, p. 649.

Subtracting from each other the two equations (4.), we find

$$(a'-a_{\prime\prime})=2S[\cos^2\overline{\sigma'}\cos 2(s'-i_s)-\cos^2\overline{\sigma_{\prime\prime}}\cos 2(s_{\prime\prime}-i_s)], \quad . \quad . \quad . \quad . \quad . \quad (5.)$$

and differentiating equations (4.), so as to express that the tide in question is a max. maximorum or min. minimorum, and subtracting, we find

$$0=\cos^2\overline{\sigma'}\sin 2(s'-i_s)-\cos^2\overline{\sigma_{\prime\prime}}\sin 2(s_{\prime\prime}-i_s). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6.)$$

In these equations (5.) and (6.), $\overline{\sigma'}$ and $\overline{\sigma_{\prime\prime}}$, are practically the declinations of the Sun at the Equinox and Solstice, *i. e.* $\overline{\sigma'}=0$ and $\overline{\sigma_{\prime\prime}}=23°\ 28'$; and s' and $s_{\prime\prime}$ are the mean values of the first column of Tables I. and II.; or $s'=1^h\ 4^m=16°$, and $s_{\prime\prime}=6^h\ 50^m=102°\ 30'$.

Hence equation (5.) becomes

$$2{\cdot}89\text{ ft.}=2S[0{\cdot}84\cos 2(16°-i_s)-\cos 2(102°\ 30'-i_s)], \quad . \quad . \quad . \quad . \quad . \quad (7.)$$

and equation (6.) becomes

$$0=0{\cdot}84\sin 2(16°-i_s)-\sin 2(102°\ 30'-i_s), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8.)$$

or

$$\tan 2i_s=\frac{\sin 25°+0{\cdot}84\sin 32°}{\cos 25°+0{\cdot}84\cos 32°},$$

or finally,

$$i_s=14°\ 5'=56^m\ 20^s. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9.)$$

Substituting this value in equation (7.), we find

$$2{\cdot}89=2S[0{\cdot}84\cos 17°\ 55'+\cos 10°\ 55'],$$

and, finally,

$$2S=\frac{289}{178}=1{\cdot}624\text{ ft.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10.)$$

Similar reasoning may be used with reference to the Solstitial Neaps and Equinoctial Springs, from which we derive the equations

$$\left.\begin{aligned} a''&=2S\cos^2\overline{\sigma''}\cos 2(s''-i_s)+2M\cos^2\overline{\mu''}\cos 2(m''-i_m),\\ a_{\prime}&=2S\cos^2\overline{\sigma_{\prime}}\cos 2(s_{\prime}-i_s)+2M\cos^2\overline{\mu_{\prime}}\cos 2(m_{\prime}-i_m),\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (11.)$$

but

$$a''=3{\cdot}15\text{ ft.}$$
$$a_{\prime}=6{\cdot}33\text{ ft.}]$$

Substituting these numerical values, and proceeding as above, we find

$$2S=\frac{318}{178}=1{\cdot}786\text{ ft.}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12.)$$

and the mean of (10.) and (12) will be

$$2S=1{\cdot}705\text{ ft.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13.)$$

C.—*Lunar Semidiurnal Tide.*

The constants of the Solar Tide being found, (9.) and (13.), nothing was easier than to calculate its amount at each Spring and Neap, and to subtract it from the former and add it to the latter. In this way the curves (α) and (β), diagram No. 1, were constructed, and represent the Lunar Semidiurnal Tide Range at Springs and Neaps respectively.

Its maximum and minimum amounts are

Maximum Lunar Range=4·62 ft.
Minimum Lunar Range=4·23 ft.

If α and α' denote the maximum and minimum Lunar Ranges which correspond with the Spring and Neap Tides of either the Solstice or Equinox, and if m and m' denote the hour-angles of the moon at these tides, we have, if $I=18\frac{1}{2}$ to $19°$ be the inclination of moon's orbit,

$$\left.\begin{aligned}\alpha&=2M\cos^2 I\,.\,\cos 2(m-i_m),\\ \alpha'&=2M\cos^2(0)\cos 2(m'-i_m).\end{aligned}\right\} \qquad (14.)$$

From which we deduce

$$\frac{\alpha}{\alpha'}=\frac{\cos^2 I\cos 2(m-i_m)}{\cos 2(m'-i_m)},$$

and

$$\tan 2i_m=\frac{\alpha\cos 2m'-\alpha'\cos^2 I\cos 2m}{-\alpha\sin 2m'+\alpha'\cos^2 I\sin 2m}. \qquad (15.)$$

But, from Tables I. and II.,

$$m=2^{h}\ 2^{m}=\ 29°\ 31',$$
$$m'=7^{h}\ 48^{m}=113°\ 14'.$$

Substituting these values in (15.), we find

$$-\tan 2i_m=\frac{462\cos(46°\ 28')+423\times\cdot 9\cos(59°\ 2')}{462\sin(46°\ 28')+423\times\cdot 9\sin(59°\ 2')},$$

or

$$-\tan 2i_m=\frac{5141}{6608}$$

$$2i_m=142°\ 7';\ [\text{or } -37°\ 53'];$$
$$i_m=\ 71°\ 3';\ [\text{or } -18°\ 56'];$$

or

$$i_m=4^{h}\ 54^{m};\ [\text{or } -1^{h}\ 18^{m}].$$

Substituting the value of i_m in the second of equations (14.), we find

$$2M=\frac{4\cdot 23}{\cos(84°\ 22')}=4\cdot 309\text{ ft.} \qquad (16.)$$

I have not been able to deduce from the observations any close approximation to the Age of the Lunar Tide, but think it is probably rather over than under five days. It would require more observations than the heights of high and low water to determine this important constant with accuracy.

D.—*Mass of the Moon and Depth of the Sea deducible from the Semidiurnal Tide.*

According to the Statical Theory of the Tides, excluding the terms depending on Parallax, Declination, Hour of Tide, &c., the ratio of the Solar to the Lunar coefficient is as follows:—

$$\frac{S}{M}=\frac{\text{mass of Sun}}{\text{mass of Moon}}\times\left(\frac{d}{D}\right)^3, \qquad (17.)$$

where D and d denote the mean distances of the Sun and Moon from the Earth. Hence we find

$$\frac{\text{mass of Sun}}{\text{mass of Moon}}=\frac{S}{M}\times\left(\frac{D}{d}\right)^3$$

$$=\frac{S}{M}\times\left(\frac{2\times 12032}{59\cdot964}\right)^3.$$

But since

$$S=1\cdot705,$$

and

$$M=4\cdot309,$$

we have

$$\frac{S}{M}=0\cdot3956, \quad \ldots\ldots \quad (18.)$$

and, finally,

$$\frac{\text{mass of Sun}}{\text{mass of Moon}}=359551\times 71\cdot11. \quad \ldots\ldots \quad (19.)$$

From which we deduce the mass of the Moon to be $\frac{1}{71\cdot11}$th of that of the Earth.

From the Dynamical Theory of the Tides given by Mr. Airy (Tides and Waves, p. 357), the ratio of S to M, for the Semidiurnal Tide, is the following:—

$$\frac{S}{M}=\frac{\text{mass of Sun}}{\text{mass of Moon}}\times\left(\frac{d}{D}\right)^3\times\frac{\frac{n^2b}{g}-\frac{k}{b}}{\frac{N^2b}{g}-\frac{k}{b}}, \quad \ldots\ldots \quad (20.)$$

where N and n are the angular velocities of the Sun and Moon, k, b the mean depth of sea and radius of earth, and g the force of gravity.

Substituting for these quantities their usual values, we find

$$\frac{S}{M}=0\cdot47288\times\frac{0\cdot00323-\frac{k}{b}}{0\cdot00345-\frac{k}{b}};$$

or

$$\frac{S}{M}=0\cdot47288\times\frac{12\cdot778-k}{13\cdot648-k}. \quad \ldots\ldots \quad (21.)$$

Substituting for $\frac{S}{M}$ its value 0·3956, we obtain by solving for k,

$$k = \text{depth of sea} = 8\cdot32 \text{ miles}. \quad \ldots\ldots \quad (22.)$$

Whatever doubt may attach to this high value of the mean depth of the Atlantic Canal, and to the depths 13·07 miles and 6·07 miles obtained from the Diurnal Tide in Part I., should properly be considered as belonging to the imperfect condition of the Theory of Canals of equal depth, as applied to such a body of water as the Atlantic Ocean, and not to the observations.

It is, however, well worthy of remark, that we can obtain from the Solitidal and Lunitidal Intervals a value for the mean depth of the sea that is much more probable, and is also very close to the depth derived from the ratio of S to M in the Diurnal Tide.

If we call the Acceleration of the Tide the difference between the Tidal Interval and

the period of half a Tide Oscillation, we find, from Mr. AIRY's Theory, the following equation for the Semidiurnal Tide:—

$$\frac{\text{Lunitidal Acceleration}}{\text{Solitidal Acceleration}}=\frac{N^2-gkm^2}{n^2-gkm^2}, \quad \ldots \ldots \ldots \quad (23.)$$

where

$$m=\frac{2\varpi}{\lambda};$$

or

$$\frac{\text{Lunitidal Acceleration}}{\text{Solitidal Acceleration}}=\frac{13{\cdot}815-4k}{12{\cdot}938-4k}. \quad \ldots \ldots \ldots \quad (24.)$$

Substituting in this equation,

$$\text{Lunitidal Acceleration}=6^{\text{h}}\ 12^{\text{m}}-4^{\text{h}}\ 54^{\text{m}}=\ 78^{\text{m}},$$

$$\text{Solitidal Acceleration}\ =6\quad 0-0\quad 56=304,$$

we find

$$\frac{78}{304}=\frac{13{\cdot}815-4k}{12{\cdot}938-4k},$$

and, finally,

$$k=\frac{3190{\cdot}6}{904}=3{\cdot}529 \text{ miles.}$$

From what we know, independently of the Tides, of the depth of the Atlantic Ocean, this value, and that found from the ratio of S to M in the Diurnal Tide, will seem nearer the truth than the higher values found from other considerations. From this it may be inferred that the theory of Tides, with friction, in these two cases, comes nearer to the truth than it does in the other cases from which the higher values are derived. I do not know why this is so, and would recommend the fact to the notice of those mathematicians who are conversant with the Theory of the Tides.

Her Majesty's Ship 'Investigator' was secured in her Winter position by Noon of the 18th day of October, the Moon's Age being 21 days. The Register of the Tides is commenced with the A.M. High Water on the 25th, four Tides before the change of the Moon.—Lat. 74° N., Long. 90° W.

Register of Tides observed at Leopold Harbour in the Month of October 1848.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
25.	A.M.	10 45	22 9½	5 0	17 4½	S.E.	6
	P.M.	11 0	23 0	5 0	18 3		
26.	A.M.	11 30	23 6	5 30	17 6½	Easterly.	7·8
	P.M.	10 0	22 6	5 30	18 6		
27.	A.M.	Noon	23 9	5 0	17 10½	S.Easterly.	3
	P.M.	......	......	6 45	18 4		
28.	A.M.	12 20	23 1	6 10	17 6½	N.Easterly.	2
	P.M.	12 30	24 4	6 45	18 10		
29.	A.M.	12 30	23 3½	6 30	18 3	S.Easterly.	3·4
	P.M.	1 0	24 6	7 30	19 1		
30.	A.M.	1 30	22 11	7 15	17 9	Variable.	1
	P.M.	1 30	24 0	7 30	18 10	Northerly.	1
31.	A.M.	2 0	21 9	7 30	17 8	”	3
	P.M.	2 0	23 7	8 0	18 10	N.Westerly.	3

Register of Tides observed at Leopold Harbour in the Month of November 1848.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	2 30	21 4	7 45	17 3	N.W.	1
	P.M.	2 40	22 8	9 0	18 4	”	
2.	A.M.	3 0	20 9	9 30	18 0	”	
	P.M.	3 30	23 0	9 30	19 10	Northerly.	5·6
3.	A.M.	3 40	21 6	9 40	19 3	”	”
	P.M.	3 40	22 8	10 30	19 6	”	”
4.	A.M.	4 30	20 6	11 15	19 0	Northerly.	6·7
	P.M.	5 10	22 7	12 30	19 0	N.Westerly.	3
5.	A.M.	6 0	20 0	Noon	19 0	Northerly.	3
	P.M.	6 10	22 0	1 0	18 6	N.Westerly.	2
6.	A.M.	7 30	20 6	1 0	18 6	”	”
	P.M.	7 45	20 1	1 10	18 9	Northerly.	5·6
7.	A.M.	8 40	21 2	2 30	18 8	N.Westerly.	5·6
	P.M.	9 30	22 4	3 0	17 9	N.Westerly.	4·5
8.	A.M.	9 10	22 3	3 30	18 7	N.Westerly.	6·7
	P.M.	10 20	22 8	4 0	17 5	N.Westerly.	6
9.	A.M.	10 15	22 9	4 20	18 2	N.Westerly.	2·3
	P.M.	11 0	22 9	5 15	16 10	”	”
10.	A.M.	10 45	22 10	5 30	18 1	”	2
	P.M.	11 30	22 11	5 0	16 6	”	1·2
11.	A.M.	12 20	22 11	5 45	17 6	S.Easterly.	4·5
	P.M.	12 30	22 9	5 45	16 3	”	6·7
12.	A.M.	12 30	22 11	6 45	17 4	S.S.E.	4
	P.M.	1 0	23 1	7 0	16 7		
13.	A.M.	12 30	22 3*	7 15	15 7		
	P.M.	12 50	22 11	7 30	17 3		
14.	A.M.	1 40	22 4	7 45	16 5		
	P.M.	1 45	24 2	8 30	17 7		
15.	A.M.	2 30	22 2	8 15	16 9		
	P.M.	2 30	23 10	9 0	17 6		
16.	A.M.	2 45	21 6	9 0	17 6		
	P.M.	3 15	23 7	10 30	18 3		
17.	A.M.	4 0	21 0	10 0	18 3		
	P.M.	5 0	23 3	11 45	18 9		
18.	A.M.	5 0	20 11	11 0	18 9		
	P.M.	5 45	22 7	......	......		
19.	A.M.	7 0	20 10	12 50	18 5		
	P.M.	7 0	22 5	1 0	19 3		
20.	A.M.	8 20	21 5	1 50	18 6		
	P.M.	8 15	22 2	2 0	19 2		
21.	A.M.	9 15	21 9	2 45	18 0		
	P.M.	9 15	21 11	3 30	18 8		
22.	A.M.	10 0	22 3	3 30	17 8		
	P.M.	10 15	22 0	4 0	18 9		
23.	A.M.	11 30	22 11	4 20	17 9		
	P.M.	11 0	22 2	4 45	18 8		
24.	A.M.	11 10	23 5	5 0	17 9		
	P.M.	11 25	22 4	5 30	18 8		
25.	A.M.	11 20	23 10	5 45	17 7		
	P.M.	Midnight	22 2	6 20	18 7		
26.	A.M.	......	......	6 0	17 7		
	P.M.	12 15	24 0	6 30	18 6		
27.	A.M.	12 30	22 9	6 20	17 6		
	P.M.	12 45	24 0	7 00	18 7		
28.	A.M.	1 0	22 0	7 00	17 6		
	P.M.	1 30	24 0	8 15	19 0		
29.	A.M.	1 30	21 11	7 30	17 10		
	P.M.	1 45	24 0	8 20	18 9		
30.	A.M.	2 15	21 9	8 0	17 11		
	P.M.	2 30	23 9	8 45	18 9		

First quarter at $3^d\ 3^h\ 18^m$, Greenwich. Full Moon at $10^d\ 13^h\ 35^m$, Greenwich.
Last quarter at $17^d\ 6^h\ 46^m$, Greenwich. New Moon at $25^d\ 9^h\ 29^m$, Greenwich.

* On the 12th found the lines attached to moorings of Pole frozen in, thereby vitiating the late semilunar tidal observations.

Register of Tides observed at Leopold Harbour in the Month of December 1848.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	2 40	21 6	8 15	18 1		
	P.M.	3 00	23 7	9 45	18 1	N.Westerly.	4·5
2.	A.M.	3 00	21 5	9 30	18 5		
	P.M.	4 00	23 3	10 45	19 1	N.Easterly.	2·3
3.	A.M.	4 00	21 6	9 45	18 10		
	P.M.	4 45	22 11	11 45	18 11	Northerly.	2·3
4.	A.M.	5 30	21 4	11 0	19 5		
	P.M.	6 0	22 8	......	......	Northerly.	3·4
5.	A.M.	6 30	21 4	0 30	18 7		
	P.M.	6 50	22 3	0 45	19 2	N.W.	4·5
6.	A.M.	8 10	21 6	1 30	17 11		
	P.M.	8 0	22 1	2 0	18 10	”	4·5
7.	A.M.	9 10	22 2	2 45	17 7		
	P.M.	8 30	22 2	3 0	18 7	”	3·4
8.	A.M.	10 0	23 4	3 30	17 4		
	P.M.	10 0	22 10	3 50	18 10	”	2·3
9.	A.M.	10 45	24 4	4 15	17 5	Northerly.	2·3
	P.M.	10 50	22 9	5 30	18 8		
10.	A.M.	Noon.	24 6	5 15	16 11	N.N.E.	3·4
	P.M.	Midnight.	22 7	6 0	17 11		
11.	A.M.	......	......	5 45	16 6	South.	2
	P.M.	12 10	24 10	6 30	17 11		
12.	A.M.	1 0	22 7	5 20	16 7	S.S.W.	1·2
	P.M.	1 0	24 10	7 30	17 8		
13.	A.M.	1 20	22 5	7 15	16 8	Calm.	0
	P.M.	2 45	24 10	8 15	17 11	”	”
14.	A.M.	2 20	22 5	8 0	17 5		
	P.M.	2 45	24 8	9 15	18 2	Northerly.	1
15.	A.M.	3 20	22 3	9 0	18 0		
	P.M.	3 30	24 3	9 45	18 5		
16.	A.M.	3 45	21 11	9 30	18 5	N.N.W.	2·3
	P.M.	4 15	23 5	10 45	18 4	S.W.	1
17.	A.M.	4 15	21 9	11 0	18 9		
	P.M.	5 40	22 7	......	......	S.Easterly.	1
18.	A.M.	6 20	21 2	12 10	18 3		
	P.M.	6 20	22 3	12 20	19 3	South.	1·2
19.	A.M.	7 30	21 7	1 10	18 8	”	
	P.M.	7 30	22 4	2 0	18 9	”	
20.	A.M.	7 50	22 2	2 0	18 10	Northerly.	1
	P.M.	8 30	22 2	2 30	19 10	”	
21.	A.M.	9 15	23 1	3 0	18 11	”	1·2
	P.M.	9 15	22 0	3 20	19 10		
22.	A.M.	10 20	23 1	3 30	18 4	Northerly.	2·3
	P.M.	10 30	22 5	4 40	19 9		
23.	A.M.	10 45	24 0	4 30	18 11	N.Westerly.	4·5
	P.M.	11 0	22 0	5 15	19 5	”	
24.	A.M.	11 30	24 11	5 0	18 6		
	P.M.	11 30	22 6	6 0	19 11	N.Westerly.	4·5
25.	A.M.	......	......	5 30	18 8	”	
	P.M.	12 30	24 7	6 20	19 3	”	
26.	A.M.	12 20	22 11	5 45	18 4	Southerly.	1·2
	P.M.	12 30	24 9	7 0	19 2		
27.	A.M.	1 0	22 7	6 30	18 4	Calm.	0
	P.M.	1 15	24 9	7 40	18 11	”	”
28.	A.M.	1 00	22 6	7 10	17 4	S.S.E.	4
	P.M.	1 40	24 7	7 30	18 10	”	”
29.	A.M.	1 30	22 7	7 15	18 2	South.	4·5
	P.M.	2 30	24 6	8 30	18 6	”	”
30.	A.M.	2 30	22 3	8 30	18 2	S.S.E.	8
	P.M.	2 45	24 2	9 20	18 4	S.E.	4
31.	A.M.	3 15	21 9	......	......	North.	1

First quarter at $3^{d}\ 8^{h}$, Greenwich.
Last quarter at $16^{d}\ 23^{h}\ 13^{m}$, Greenwich.
Full Moon at $9^{d}\ 23^{h}\ 45^{m}$, Greenwich.
New Moon at $25^{d}\ 4^{h}\ 21^{m}$, Greenwich.

Register of Tides observed at Leopold Harbour in the Month of January 1849.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	4 0	21 5	9 40	17 11	S.S.E.	7
	P.M.	3 40	22 7	10 30	17 11	,,	6·7
2.	A.M.	4 30	21 2	9 30	18 9	S.Easterly.	5·6
	P.M.	6 0	22 5	......	......	S.S.E.	5·6
3.	A.M.	6 10	21 6	12 10	17 10	S.Easterly.	5·6
	P.M.	6 20	22 5	12 30	19 0	S.S.E.	5·6
4.	A.M.	7 0	22 0	12 30	18 1	,,	4·5
	P.M.	7 30	22 0	1 20	19 1	,,	3·4
5.	A.M.	8 30	22 6	2 0	17 6	N.Westerly.	3·4
	P.M.	8 20	21 11	3 10	18 10	,,	2·0
6.	A.M.	9 40	22 11	2 45	17 1	N.W.	3·4
	P.M.	10 0	21 10	4 30	18 6	,,	6·7
7.	A.M.	10 30	24 1	4 30	17 0	Variable.	,,
	P.M.	11 20	22 4	5 0	18 9	N.N.Westerly.	2·3
8.	A.M.	11 15	24 5	5 0	17 0	Variable.	,,
	P.M.	11 40	22 5	5 50	18 4	S.Easterly.	3·4
9.	A.M.	11 30	25 2	5 45	16 10	,,	
	P.M.	......	......	6 30	18 5	N.Westerly.	2·3
10.	A.M.	12 20	23 2	6 20	17 2	,,	,,
	P.M.	......	25 2	7 30	18 1	,,	1·2
11.	A.M.	1 15	22 7	7 15	17 0	Variable.	1
	P.M.	1 30	25 1	8 15	17 9	Westerly.	1
12.	A.M.	2 0	22 6	8 0	17 0	N.Westerly.	2
	P.M.	2 15	24 4	8 30	17 6	Northerly.	3·4
13.	A.M.	2 40	22 6	8 30	17 11	,,	4
	P.M.	2 30	24 6	9 40	18 8	N.Westerly.	4·5
14.	A.M.	3 15	22 7	9 30	18 6	,,	4
	P.M.	3 30	23 9	9 15	18 5	,,	4
15.	A.M.	4 30	22 3	10 30	18 10	Northerly.	4·5
	P.M.	4 30	22 11	10 30	18 6	,,	4·5
16.	A.M.	5 0	22 2	10 50	19 8	N.Westerly.	6·7
	P.M.	5 30	22 9	11 30	18 10	N. by E.	7
17.	A.M.	6 0	21 11	1 30	19 11	N.N.W.	4·5
	P.M.	6 30	21 10	......	......	,,	4
18.	A.M.	7 15	21 9	12 50	18 8	N.N.E.	4·5
	P.M.	7 15	21 6	1 30	19 9	N.Westerly.	5·6
19.	A.M.	8 40	22 1	2 15	18 6	N.N.W.	5·6
	P.M.	8 50	21 0	3 0	19 9	Northerly.	5·6
20.	A.M.	10 0	22 7	3 15	18 4	,,	1·2
	P.M.	9 30	21 10	4 15	19 6	N.W. to S.E.	1·2
21.	A.M.	10 50	23 4	3 30	18 4	S.Easterly.	4·2
	P.M.	10 30	22 2	5 0	19 10	,,	3
22.	A.M.	11 15	24 1	4 30	18 9	,,	3
	P.M.	11 0	22 5	5 15	19 4	,,	4·5
23.	A.M.	11 30	24 5	5 20	18 7	Northerly.	4
	P.M.	11 30	22 2	6 30	19 4	Calm.	0
24.	A.M.	......	......	5 45	17 9	N.N.W.	1·2
	P.M.	12 30	24 2	6 40	18 8	,,	1·2
25.	A.M.	12 20	22 3	6 15	17 4	,,	2
	P.M.	1 0	24 1	7 25	18 3	,,	1·2
26.	A.M.	1 0	22 2	7 0	17 5	Southerly.	4·5
	P.M.	1 15	24 3	7 45	17 11	,,	3
27.	A.M.	1 30	22 3	7 15	17 4	,,	3·4
	P.M.	2 15	24 1	8 30	17 8	Northerly.	2·3
28.	A.M.	2 0	22 3	8 0	17 2	N.N.W.	5
	P.M.	3 0	23 8	9 0	17 8	,,	6
29.	A.M.	2 15	22 5	8 45	17 11	N.Westerly.	8·9
	P.M.	3 20	23 9	9 50	18 0	,,	7·8
30.	A.M.	3 45	22 8	9 30	18 6	,,	3
	P.M.	3 50	23 5	10 0	18 1	N.N.W.	2
31.	A.M.	4 20	22 4	10 50	18 10	,,	1
	P.M.	5 0	22 10	11 0	18 0	N.Westerly.	3

First quarter at 1^{d} 19^{h} 38^{m}, Greenwich.
Last quarter at 15^{d} 18^{h} 54^{m}, Greenwich.
First quarter at 31^{d} 4^{h} 42^{m}, Greenwich.

Full Moon at 8^{d} 10^{h} 50^{m}, Greenwich.
New Moon at 23^{d} 22^{h}, Greenwich.

Register of Tides observed at Leopold Harbour in the Month of February 1849.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	5 40	22 2	11 35	19 5	N.N.W.	6
	P.M.	5 30	23 1	11 20	19 0	N.Westerly.	8
2.	A.M.	6 55	23 4	......	......	"	8
	P.M.	7 0	21 11	1 30	20 3	"	5
3.	A.M.	8 0	22 5	1 30	17 10	S.S.E.	3
	P.M.	8 20	21 4	2 30	19 1	N.Westerly.	2
4.	A.M.	9 15	22 9	2 30	17 6	Northerly.	1
	P.M.	9 30	21 4	4 20	18 8	"	3
5.	A.M.	10 40	23 5	3 30	17 3	N.N.W.	6
	P.M.	10 30	22 0	5 0	18 5	"	6
6.	A.M.	11 15	24 5	4 30	17 5	"	6
	P.M.	11 30	23 5	5 45	18 4	"	6
7.	A.M.	11 45	24 5	5 30	17 3	"	8
	P.M.	......	......	6 30	17 8	"	7
8.	A.M.	12 30	22 3	6 15	16 6	"	7
	P.M.	12 40	24 2	7 0	17 6	N.Westerly.	7
9.	A.M.	1 0	22 6	7 0	16 6	"	8
	P.M.	1 0	23 10	7 40	17 4	N.N.W.	7
10.	A.M.	1 30	22 9	7 45	17 4	"	7
	P.M.	1 50	24 2	8 30	17 8	N.Westerly.	8
11.	A.M.	2 0	22 10	8 15	17 6	"	6
	P.M.	2 30	23 6	8 40	17 9	"	7
12.	A.M.	3 10	22 10	9 15	18 6	"	9
	P.M.	2 45	23 10	9 40	18 3	N.W.	6
13.	A.M.	3 15	22 3	9 30	18 2	N.Westerly.	4
	P.M.	3 30	22 6	9 45	17 8	"	2
14.	A.M.	4 30	21 5	10 30	18 5	S.S.E.	1 to 6
	P.M.	4 30	21 8	10 30	18 4	"	7
15.	A.M.	5 0	21 10	11 20	19 6	Southerly.	7
	P.M.	5 0	21 4	11 30	18 2	S. by E.	5
16.	A.M.	6 30	21 3	12 30	19 6	S.S.E.	5
	P.M.	6 10	21 0	......	......	"	7
17.	A.M.	7 30	32 7	12 30	19 1	"	7
	P.M.	7 30	21 5	2 15	20 6	"	7
18.	A.M.	8 30	22 11	2 0	19 6	"	7
	P.M.	9 0	21 6	3 30	20 3	"	9
19.	A.M.	10 0	23 1	3 0	19 3	"	9
	P.M.	10 0	21 2	4 30	19 6	S.Easterly	6
20.	A.M.	10 40	22 11	4 0	18 1	Southerly.	3·1
	P.M.	11 0	21 1	5 15	18 4	Calm.	0
21.	A.M.	11 30	23 0	5 0	17 7	S.Westerly.	1
	P.M.	......	......	5 30	17 11	Calm.	0
22.	A.M.	12 20	21 4	5 45	17 5	Southerly.	1
	P.M.	12 15	23 2	6 30	17 6	Northerly.	1
23.	A.M.	12 15	21 8	6	16 9	N.N.W.	2
	P.M.	12 30	23 3	7 0	16 8	Calm.	0
24.	A.M.	12 45	21 6	6 30	15 11	Northerly.	1
	P.M.	1 0	22 10	7 15	16 1	Calm.	0
25.	A.M.	12 45	21 9	7 20	15 8	"	0
	P.M.	1 45	22 8	8 0	15 10	N.N.W.	3
26.	A.M.	1 45	21 0	7 40	16 3	N.Easterly.	6
	P.M.	2 0	23 7	8 15	17 3	Easterly.	7
27.	A.M.	2 28	22 11	8 30	17 6	N.Westerly.	5
	P.M.	1 45	23 0	9 0	17 9	"	5
28.	A.M.	3 0	22 9	9 15	17 10	"	5
	P.M.	3 15	22 0	9 30	17 5	N.W. to S.E.	4·2

Full Moon at $6^d\ 23^h\ 15^m$, Greenwich. Last quarter at $14^d\ 6^h\ 2^m$, Greenwich.
New Moon at $22^d\ 13^h\ 29^m$, Greenwich.

Register of Tides observed at Leopold Harbour in the Month of March 1849.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	4 30	22 4	10 30	18 0	Calm.—N.W.	0·4
	P.M.	4 30	21 10	10 30	17 6	N.Westerly.	2
2.	A.M.	5 30	22 3	11 20	18 10	S.S.E.	2
	P.M.	5 30	21 8	11 30	18 3	S.	2
3.	A.M.	6 40	22 8	......	......	Calm and Variable.	2·3
	P.M.	6 45	21 6	1 30	19 0		
4.	A.M.	7 30	22 9	1 10	18 6	S.Easterly.	4
	P.M.	8 20	21 7	2 45	19 5	"	4·7
5.	A.M.	9 0	23 5	2 30	18 8	"	5
	P.M.	9 45	21 11	4 20	19 1	"	7·3
6.	A.M.	10 0	23 4	4 0	17 9	"	3·2
	P.M.	11 15	22 2	4 45	18 4	"	3·7
7.	A.M.	11 10	24 4	4 30	18 4	E.S.E.	6·7
	P.M.	11 20	23 0	5 45	18 8	Easterly.	8·9
8.	A.M.	Noon	24 7	5 30	18 1	S.E.	7·4
	P.M.	......	......	6 25	18 4	S.S.E.	2
9.	A.M.	12 15	23 1	6 15	17 4	N.N.W.	1
	P.M.	12 30	23 10	6 20	17 7	N.N.E.	2
10.	A.M.	12 45	22 11	7 0	17 0	N.Westerly.	2
	P.M.	1 0	23 8	7 15	17 3	"	2
11.	A.M.	1 30	22 11	7 45	16 0	"	3
	P.M.	1 40	23 4	8 0	17 5	"	6
12.	A.M.	1 50	23 1	8 15	17 8	"	5
	P.M.	2 30	23 2	8 30	17 6	W.N.W.	6
13.	A.M.	2 0	23 0	8 30	18 5	"	6
	P.M.	2 30	23 1	8 20	17 10	"	7
14.	A.M.	3 0	22 10	9 30	18 6	"	9
	P.M.	3 0	22 4	9 20	18 0	"	6
15.	A.M.	3 30	22 8	9 45	19 2	N.Westerly.	5
	P.M.	3 30	22 1	10 10	18 7	"	2
16.	A.M.	4 30	22 5	10 30	19 10	N.N.W.—S.S.E.	1·1
	P.M.	4 0	21 7	11 0	18 11	S.E.'ly.—S.W.'ly.	1·3
17.	A.M.	5 30	22 6	11 45	20 5	Calm.	"
	P.M.	4 45	21 8	12 0	19 8	Easterly.	6
18.	A.M.	6 40	22 6	1 30	20 3	"	4
	P.M.	6 45	21 3	......	......	N.Easterly.	4
19.	A.M.	7 45	22 5	1 0	19 9	"	4
	P.M.	8 30	21 0	3 15	19 8	"	5
20.	A.M.	9 30	22 8	2 30	19 5	"	6
	P.M.	9 45	21 3	4 20	19 4	"	5
21.	A.M.	10 0	23 2	3 30	19 1	Northerly.	3
	P.M.	10 31	21 11	4 30	19 0	"	1
22.	A.M.	10 45	23 9	4 30	19 0	"	3
	P.M.	11 0	22 7	5 30	18 10	"	4
23.	A.M.	11 10	23 11	5 0	18 7	"	2
	P.M.	11 40	22 5	5 45	17 11	Calm.	"
24.	A.M.	......	......	5 30	17 6	"	"
	P.M.	12 5	23 9	6 20	17 4	Southerly.	2
25.	A.M.	12 25	22 9	6 15	16 11	S.S.Easterly.	3
	P.M.	12 40	23 1	6 45	16 0	"	3
26.	A.M.	1 15	22 11	7 0	16 4	"	5
	P.M.	1 30	22 9	7 10	16 2	"	5
27.	A.M.	1 30	23 5	7 50	16 10	"	5
	P.M.	2 20	23 0	8 0	16 6	Southerly.	4
28.	A.M.	2 30	23 7	8 30	17 2	Easterly.	4
	P.M.	2 20	22 8	8 45	17 0	Northerly.	1
29.	A.M.	3 15	23 8	9 10	18 1	Easterly.	7
	P.M.	3 0	22 7	9 15	17 10	"	7
30.	A.M.	3 45	23 6	10 30	18 9	N.Easterly.	5
	P.M.	3 50	21 9	10 15	17 11	N.Westerly.	5
31.	A.M.	5 0	22 11	11 30	19 0	Northerly.	2
	P.M.	5 15	21 1	11 30	18 5	Southerly.	3

First quarter at $1^d\ 12^h$, Greenwich. Full Moon at $8^d\ 13^h$, Greenwich. Last quarter at $16^d\ 12^h$, Greenwich.
New Moon at $24^d\ 2^h$, Greenwich. First quarter at $30^d\ 19^h$, Greenwich.

Register of Tides observed at Leopold Harbour in the Month of April 1849.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	6 20	23 0	......	......	E.S.E.	6
	P.M.	7 20	21 6	1 0	19 5	"	8
2.	A.M.	7 20	23 0	12 20	19 0	"	8
	P.M.	8 30	21 6	2 15	19 3	N.Easterly.	4
3.	A.M.	8 40	23 4	2 20	19 1	"	4
	P.M.	9 50	22 4	4 0	19 1	"	4
4.	A.M.	10 0	23 11	3 30	19 4	N.Westerly.	3
	P.M.	10 30	22 7	4 30	18 11	"	2
5.	A.M.	10 30	23 3	4 15	18 5	"	4
	P.M.	11 0	22 6	5 20	17 10	Calm.	0
6.	A.M.	11 20	23 3	5 15	17 9	"	0
	P.M.	11 50	23 10	5 30	17 8	Northerly.	1
7.	A.M.	12 0	23 6	6 0	17 10	Calm.	
	P.M.	......	......	6 15	17 11	N.Westerly.	2
8.	A.M.	0 20	23 9	6 30	18 2	"	3
	P.M.	0 30	23 7	6 30	17 9	N.N.W.	3
9.	A.M.	0 45	23 8	5 45	17 10	"	2
	P.M.	1 0	22 11	7 10	17 7	N.N.E.	4
10.	A.M.	1 0	23 8	7 30	18 2	N.Easterly.	4
	P.M.	1 30	22 7	7 30	18 0	"	5
11.	A.M.	1 50	23 7	8 30	18 3	Northerly.	2
	P.M.	2 30	22 3	8 10	18 1	Southerly.	2
12.	A.M.	2 30	24 0	8 45	19 3	Northerly.	3
	P.M.	2 30	22 7	8 45	18 3	N.N.W.	3
13.	A.M.	3 15	23 0	9 30	18 8	Variable.	2
	P.M.	3 0	21 3	9 0	18 0	S.S.E.	1
14.	A.M.	3 35	22 6	10 35	18 10	"	3
	P.M.	3 30	20 11	9 45	18 5	"	5
15.	A.M.	5 0	22 2	11 30	19 1	"	6
	P.M.	4 45	20 9	10 45	18 9	"	6
16.	A.M.	5 30	22 2	......	......	"	4
	P.M.	6 30	20 7	12 30 11 30	19 4 19 3	"	3
17.	A.M.	7 0	22 3	2 30	19 4	"	3
	P.M.	8 30	21 0	......	......	"	"
18.	A.M.	8 30	23 0	1 30	19 8	Southerly.	2
	P.M.	9 30	21 9	3 30	19 6	N.Westerly.	9
19.	A.M.	9 15	23 2	3 15	19 5	"	6
	P.M.	9 45	21 6	4 20	19 0	"	8
20.	A.M.	10 0	23 2	4 0	19 0	"	7
	P.M.	11 0	23 1	4 15	18 6	"	4
21.	A.M.	10 50	23 9	4 30	18 11	S.S.E.	2
	P.M.	11 15	23 9	5 15	18 2	"	4
22.	A.M.	11 40	23 9	5 30	18 5	N.N.W.	2
	P.M.	12 0	24 2	5 45	17 8	"	2
23.	A.M.	12 0	23 9	5 45	18 0	Northerly.	3
	P.M.	......	......	6 20	17 5	"	2
24.	A.M.	12 40	24 7	7 0	17 10	"	3
	P.M.	12 40	23 3	7 0	16 11	"	5
25.	A.M.	1 15	24 7	7 30	17 9	N.N.E.	4
	P.M.	1 20	22 11	7 30	17 0	"	6
26.	A.M.	2 0	24 6	8 20	18 0	N.Easterly.	5
	P.M.	2 15	22 6	8 20	17 0	N.N.W.	3
27.	A.M.	3 0	24 0	9 0	17 11	N. by E.	4
	P.M.	3 30	21 7	9 10	17 3	N.N.E.	5
28.	A.M.	4 0	23 5	10 30	18 0	"	3
	P.M.	4 15	22 1	10 0	17 11	N.Westerly.	6
29.	A.M.	4 45	23 5	11 30	18 9	"	5
	P.M.	5 10	21 5	11 20	18 11	"	2
30.	A.M.	5 45	23 4	......	......	S.S.E.	2
	P.M.	6 40	21 6	12 50	19 2	"	1

Full Moon at $7^{d}\ 3^{h}\ 49^{m}$, Greenwich. Last quarter at $15^{d}\ 7^{h}\ 7^{m}$, Greenwich.
New Moon at $22^{d}\ 11^{h}\ 54^{m}$, Greenwich. First quarter at $29^{d}\ 2^{h}\ 17^{m}$, Greenwich.

Register of Tides observed at Leopold Harbour in the Month of May 1849.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	7 15	23 2	12 35	19 5	N.N.W.	1
	P.M.	8 30	21 9	2 30	18 11	N. Westerly.	3
2.	A.M.	8 30	23 1	2 0	19 5	N.N.E.	3
	P.M.	9 15	22 3	3 30	18 8	"	4
3.	A.M.	......	......	2 45	19 2	Northerly.	3
	P.M.	10 15	22 9	4 20	18 5	"	3
4.	A.M.	10 15	23 1	4 15	19 0	"	5
	P.M.	10 20	23 9	4 30	18 5	N.N.E.	4
5.	A.M.	11 0	23 4	5 0	18 9	"	3
	P.M.	11 45	23 10	5 0	18 5	"	3
6.	A.M.	11 30	23 0	5 50	18 11	Northerly.	3
	P.M.	12 10	23 9	5 30	17 9	N.N.W.	5
7.	A.M.	12 15	23 7	6 15	18 6	S.Easterly.	2
	P.M.	12 30	23 10	6 0	17 6	Southerly.	2
8.	A.M.	12 30	22 4	6 45	18 4	Variable.	1·3
	P.M.	......	......	6 30	17 9	Easterly.	7
9.	A.M.	0 45	24 2	7 0	18 11	"	7
	P.M.	0 50	22 10	7 0	18 3	Southerly.	2
10.	A.M.	1 30	24 2	8 0	18 7	Variable.	2·4
	P.M.	1 40	21 9	8 0	17 9	"	3
11.	A.M.	2 20	23 7	8 40	18 7	S.S.E.	5
	P.M.	2 30	21 8	8 30	18 1	Southerly.	5
12.	A.M.	3 0	23 8	9 15	19 2	Variable.	2
	P.M.	2 40	21 9	9 15	18 6	S.S.E.	2
13.	A.M.	3 20	23 5	10 15	19 2	"	2
	P.M.	3 20	21 4	9 30	18 10	"	2
14.	A.M.	4 15	23 1	11 10	19 2	"	4
	P.M.	4 10	21 0	10 19	19 3	Easterly.	5
15.	A.M.	5 0	22 11	12 0	19 4	S.Easterly.	4
	P.M.	6 0	21 2	11 0	19 7	"	4
16.	A.M.	6 0	22 11	......	......	"	5
	P.M.	7 30	21 7	1 20	19 5	"	4
17.	A.M.	7 15	22 11	0 45	19 11	Easterly.	3
	P.M.	8 30	21 11	2 30	19 1	S.E.	3
18.	A.M.	8 30	22 8	2 0	19 8	N.Easterly.	5
	P.M.	9 30	22 0	3 0	18 4	Northerly.	1
19.	A.M.	9 15	22 5	3 20	18 8	N.Westerly.	4
	P.M.	10 15	22 7	4 0	17 7	"	4
20.	A.M.	10 15	22 7	4 15	18 6	N.N.W.	5
	P.M.	10 40	23 2	4 20	17 3	N.Westerly.	4
21.	A.M.	11 0	22 5	5 0	18 2	N.N.W.	2
	P.M.	12 0	24 4	5 20	17 0	S.S.E.	2
22.	A.M.	11 30	23 2	6 0	18 4	Northerly.	2
	P.M.	12 15	24 11	6 5	17 1	S.S.E.	2
23.	A.M.	12 20	23 3	6 45	18 5	"	2
	P.M.	......	......	6 30	17 3	N.N.W.	3
24.	A.M.	1 0	25 3	7 30	18 4	"	2
	P.M.	1 15	23 4	7 0	17 7	N.Westerly.	3
25.	A.M.	2 0	25 5	8 15	18 1	Calm.	0
	P.M.	1 30	22 10	8 15	17 8	N.Westerly.	6
26.	A.M.	2 45	25 0	9 30	18 7	"	7
	P.M.	2 45	22 6	9 0	18 1	"	5
27.	A.M.	3 30	24 7	10 30	18 9	"	5
	P.M.	4 0	22 0	9 45	18 5	"	6
28.	A.M.	4 40	23 11	11 20	18 8	"	5
	P.M.	4 0	21 4	10 45	18 11	"	3
29.	A.M.	5 30	23 5	11 45	18 11	"	2
	P.M.	6 40	21 10	11 40	19 8	Variable.	1
30.	A.M.	6 30	23 5	......	......	Easterly.	2
	P.M.	8 0	22 3	1 30	19 1	"	1
31.	A.M.	8 15	23 1	1 30	19 11	Northerly.	2
	P.M.	8 15	22 8	2 20	19 1	"	2

Full Moon at 6^{d} 19^{h}, Greenwich.
New Moon at 21^{d} 19^{h}, Greenwich.
Last quarter at 14^{d} 22^{h}, Greenwich.
First quarter at 28^{d} 11^{h}, Greenwich.

Register of Tides observed at Leopold Harbour in the Month of June 1849.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	8 45	22 9	2 30	19 9	Northerly.	1
	P.M.	9 30	23 6	3 0	18 8	N.N.W.	2
2.	A.M.	9 20	22 11	3 30	19 9	,,	4
	P.M.	10 30	23 7	3 45	18 9	,,	3
3.	A.M.	10 20	22 9	4 30	19 9	,,	4
	P.M.	11 0	24 2	4 30	18 10	,,	4
4.	A.M.	11 0	22 9	5 15	19 9	,,	5
	P.M.	11 40	24 4	5 0	18 10	,,	7
5.	A.M.	11 30	22 9	5 50	19 7	,,	6
	P.M.	12 10	24 6	5 30	18 8	,,	7
6.	A.M.	......	......	6 45	19 7	N.Westerly.	7
	P.M.	12 15	22 8	6 10	18 8	,,	7
7.	A.M.	12 45	24 6	7 20	19 2	,,	7
	P.M.	1 10	22 4	6 45	18 5	,,	5
8.	A.M.	1 30	24 5	7 45	19 2	Northerly.	2
	P.M.	1 30	22 5	7 30	18 4	,,	1
9.	A.M.	1 45	24 2	8 30	19 4	N.Easterly.	3
	P.M.	2 0	22 3	7 30	18 11	E.N.E.	6
10.	A.M.	2 20	24 4	9 0	19 4	Easterly.	5
	P.M.	2 40	22 2	8 30	19 1	N.N.E.	2
11.	A.M.	3 15	24 3	9 15	18 10	E.N.E.	6
	P.M.	3 0	21 4	9 15	18 7	,,	6
12.	A.M.	3 20	23 5	10 20	18 11	Variable.	2
	P.M.	3 40	21 7	10 0	19 4	N.Westerly.	1
13.	A.M.	4 30	23 7	11 20	19 4	N.N.E.	3
	P.M.	5 0	21 10	11 0	19 8	,,	1
14.	A.M.	5 15	23 5	12 0	19 5	Variable.	1
	P.M.	5 30	22 0	12 0	20 0	Easterly.	2
15.	A.M.	6 30	23 1	......	......	,,	6
	P.M.	7 30	22 4	1 15	18 11	,,	6
16.	A.M.	7 50	22 9	1 30	19 9	S.Easterly.	2
	P.M.	9 0	22 10	2 15	18 6	Variable.	1
17.	A.M.	8 30	22 9	1 45	19 7	S.Easterly.	4
	P.M.	10 45	23 6	3 0	18 1	,,	2
18.	A.M.	9 30	22 8	3 40	19 3	E.S.E.	3
	P.M.	10 30	24 2	3 45	17 9	,,	5
19.	A.M.	10 30	22 11	5 0	19 0	Easterly.	2
	P.M.	11 30	24 9	4 40	17 7	Northerly.	2
20.	A.M.	11 15	22 10	6 0	18 8	Easterly.	2
	P.M.	12 0	25 0	5 30	17 1	,,	4
21.	A.M.	......	......	6 30	18 4	,,	4
	P.M.	12 30	23 0	6 10	17 3	Variable.	2
22.	A.M.	12 40	25 5	7 15	18 3	N.N.E.	2
	P.M.	1 10	22 0	7 15	17 3	N.Easterly.	3
23.	A.M.	1 30	25 4	8 30	18 4	,,	2
	P.M.	1 50	23 6	7 40	17 10	,,	2
24.	A.M.	2 15	25 3	8 50	18 5	Northerly.	1
	P.M.	2 30	22 9	8 30	18 3	Southerly.	2
25.	A.M.	3 15	24 11	9 30	18 5	Variable.	1
	P.M.	3 20	22 5	9 30	18 9	S.S.E.	2
26.	A.M.	3 50	24 4	10 30	18 5	,,	5
	P.M.	4 30	22 3	10 30	19 2	S.Westerly.	5
27.	A.M.	4 45	23 7	10 30	18 9	S.S.E.	5
	P.M.	5 30	22 1	11 30	19 5	,,	5
28.	A.M.	5 40	23 2	......	......	,,	4
	P.M.	7 0	22 5	12 30	18 11	,,	5
29.	A.M.	7 0	22 10	12 50	20 2	,,	3
	P.M.	8 20	22 7	1 30	19 0	,,	1
30.	A.M.	8 0	22 7	2 30	20 0	,,	1
	P.M.	9 0	23 3	2 30	19 0	,,	2

Full Moon at 5^d 16^h, Greenwich. Last quarter at 13^d 10^h, Greenwich.
New Moon at 20^d 2^h, Greenwich. First quarter at 26^d 22^h, Greenwich.

Register of Tides observed at Leopold Harbour in the Month of July 1849.

Day.		High Water.		Low Water.		Wind.	
		Time.	Height.	Time.	Height.	Direction.	Force.
		h m	ft. in.	h m	ft. in.		
1.	A.M.	9 30	22 7	3 15	20 4	S.S.E.	4
	P.M.	9 45	23 10	3 15	19 0	„	4
2.	A.M.	10 0	22 6	4 15	20 3	Variable.	1
	P.M.	10 45	24 0	4 30	18 11	Northerly.	2
3.	A.M.	10 40	22 5	5 15	19 2	N.Westerly.	4
	P.M.	11 15	24 2	5 0	18 7	„	5
4.	A.M.	11 30	22 5	5 50	19 8	„	4
	P.M.	11 50	24 6	5 15	18 6	„	4
5.	A.M.	11 50	22 8	6 0	19 6	„	5
	P.M.	Midnight.	24 9	5 45	18 7	„	2
6.	A.M.	......	......	6 45	19 4	„	3
	P.M.	12 30	22 10	6 20	18 4	„	2
7.	A.M.	12 50	24 9	7 10	19 4	„	2
	P.M.	12 50	22 9	7 0	18 6	„	3
8.	A.M.	1 20	24 10	8 0	18 11	„	5·6
	P.M.	1 30	22 6	7 20	18 2	„	6
9.	A.M.	2 0	24 6	8 45	18 10	Variable.	2
	P.M.	2 0	22 6	8 0	18 7	S.S.E.	3
10.	A.M.	3 0	24 6	9 0	19 1	S.Easterly.	4
	P.M.	3 0	22 7	8 50	19 0	Northerly.	2
11.	A.M.	3 20	24 5	9 50	19 3	„	3
	P.M.	3 20	23 0	9 20	19 8	„	2
12.	A.M.	3 45	24 8	10 40	19 10	Variable.	2
	P.M.	4 0	23 2	10 15	20 2	N.Westerly.	4
13.	A.M.	5 0	24 0	11 30	19 5	„	4
	P.M.	5 40	22 11	11 0	20 5	Variable.	2
14.	A.M.	5 30	23 10	12 20	19 7	N.Westerly.	2
	P.M.	7 0	23 2	......	......	„	3
15.	A M.	6 45	23 1	1 0	20 4	„	4
	P.M.	8 0	23 6	1 0	19 10	„	3
16.	A.M.	8 0	22 10	2 10	20 4	„	2
	P.M.	9 15	23 10	2 30	18 7	„	2
17.	A.M.	9 0	22 9	3 20	19 10	S.S.E.	2
	P.M.	10 10	24 8	3 10	18 8	„	3
18.	A.M.	10 0	23 0	4 15	19 7	„	3
	P.M.	10 45	25 3	4 15	18 0	N.Westerly.	3
19.	A.M.	11 0	23 1	5 30	19 1	„	5
	P.M.	11 45	25 5	5 0	17 8	„	5
20.	A.M.	11 45	23 3	6 30	18 8	„	3
	P.M.	......	......	6 15	17 8	„	4
21.	A.M.	12 30	25 8	7 15	18 7	Northerly.	4
	P.M.	12 30	23 6	6 40	17 6	„	3
22.	A.M.	1 15	25 5	7 50	18 1	„	1
	P.M.	1 15	23 2	7 30	17 5	„	2
23.	A.M.	2 0	25 1	8 30	17 11	„	1
	P.M.	2 0	22 11	8 0	17 7	N.N.E.	2
24.	A.M.	2 30	24 5	9 20	17 11	„	3
	P.M.	2 45	22 9	9 15	18 2	„	4
25.	A.M.	3 15	23 11	9 45	18 1	Northerly.	5
	P.M.	3 40	22 4	9 40	18 7	N.Westerly.	4
26.	A.M.	4 0	23 3	10 30	18 6	N.W.	6
	P.M.	4 0	22 4	10 20	19 4	„	7
27.	A.M.	4 30	22 10	11 20	18 10	„	6
	P.M.	5 40	22 4	11 30	20 0	„	6
28.	A.M.	5 30	22 6	......	......	N.Westerly.	5
	P.M.	7 0	22 9	12 30	19 3		
29.	A.M.	6 30	22 5	1 0	20 8		
	P.M.	8 10	23 0	1 40	19 5		
30.	A.M.	8 10	22 2	2 30	20 7	N.Easterly.	3
	P.M.	9 0	23 6	2 30	19 5	E.N.E.	4
31.	A.M.	9 15	22 3	3 45	20 6	„	6
	P.M.	10 10	23 4	3 50	19 4	East.	6

Full Moon at 5^d 1^h, Greenwich.
New Moon at 19^d 9^h Greenwich.

Last quarter at 12^d 19^h Greenwich.
First quarter at 26^d 12^h Greenwich.

Register of Tides observed at Leopold Harbour in the Month of August 1849.

Day.	High Water.		Low Water.		Wind.	
	Time.	Height.	Time.	Height.	Direction.	Force.
	h m	ft. in.	h m	ft. in.		
1. A.M.	10 15	22 5	4 45	20 3	E.S.E.	7
P.M.	10 45	24 8	4 0	19 4	N.Easterly.	6
2. A.M.	10 50	22 9	5 20	20 3	E.S.E.	5·6
P.M.	11 45	23 0	6 0	19 10	,,	6
3. A.M.	11 55	25 0	5 15	18 10	Easterly.	4
P.M.	12 0	23 2	6 30	19 5	S.Easterly.	5
4. A.M.	Noon.	23 2	6 30	19 5	,,	6
P.M.	,,	......	6 0	18 9	Variable.	3·7
5. A.M.	12 30	25 3	7 30	19 6	S.Easterly.	7
P.M.	12 0	23 5	6 30	18 4	,,	6
6. A.M.	1 0	25 1	7 20	18 11	Southerly.	4
P.M.	1 15	23 3				
Full Moon at 3^d 13^h.						

Explanation of the MS. Diagram accompanying this Paper, referred to in page 243.

This diagram was formed by laying down on ruled paper the observations of height recorded in the Tables of Observation.

The alternate high waters were then joined by lines, forming two curves, the distance between which is double the Diurnal Tide at the time of High Water.

The same construction was made for the Low Waters. As the Diurnal Tide vanishes with the declination, the equinoctial Diurnal Tide is altogether Lunar; accordingly the Lunar Diurnal Tide was found from the equinoctial portion of the diagram.

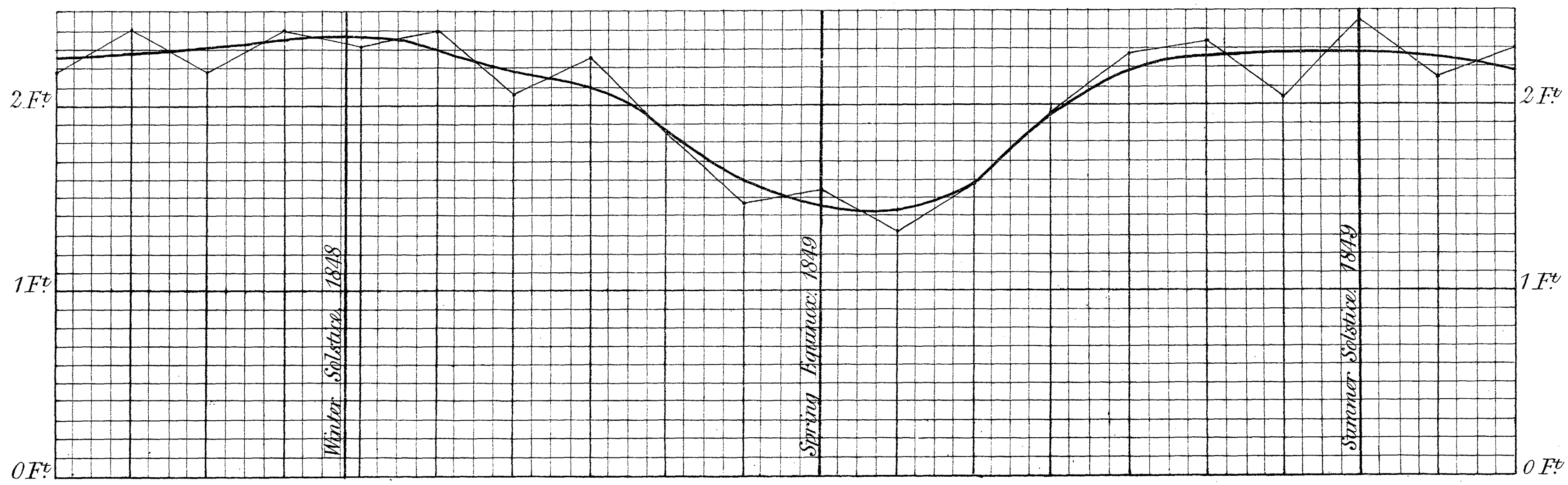
When found, it was superposed on the Solstitial portion of the diagrams,—the points of intersection being found by means of the interval from $\mu=0$ to $D=0$, or age of tide already obtained from the equinoctial observations.

The part of the diurnal curves remaining, after the superposition of the Lunar Tide, was the Solar Diurnal Tide.

The Lunar and Solar Tides at High and Low Water having been thus found, their remaining constants, viz. Coefficients and Tidal Intervals, were worked out, as shown in the paper itself.

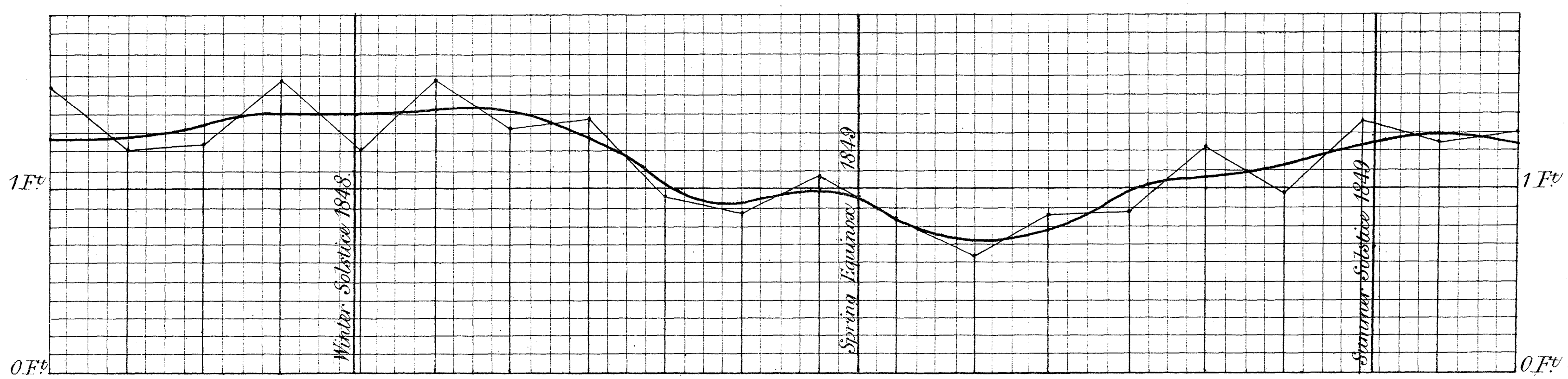
A Curve, drawn bisecting the range of the Diurnal Tide at High Water, and another curve in like manner at Low Water, give the High and Low Water Curves of the Semidiurnal Tides that I have used in the second part of my paper on the Arctic Tides. This part of the subject is given in detail in the paper itself.

Fig. I.



Range of Diurnal Tide, at High Water, at Port Leopold, from November 1848 to July 1849.

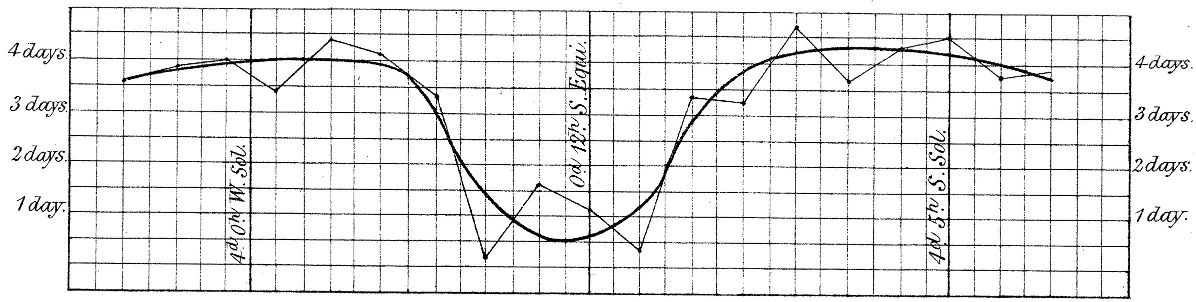
Fig. II.



Range of Diurnal Tide, at Low Water, at Port Leopold, from November 1848 to July 1849.

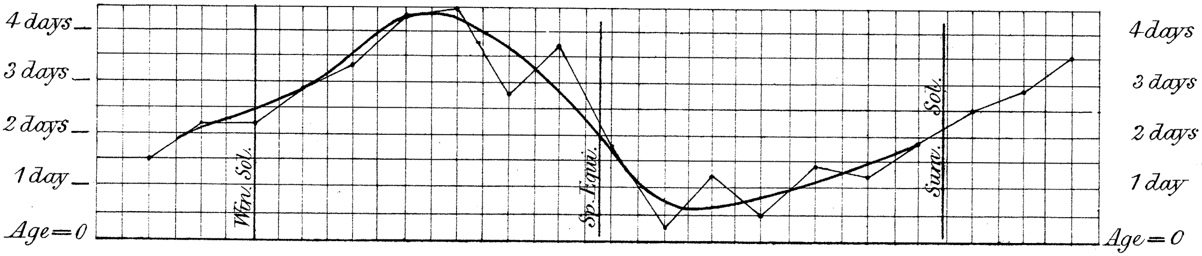
J. Basire lith.

Fig. III.



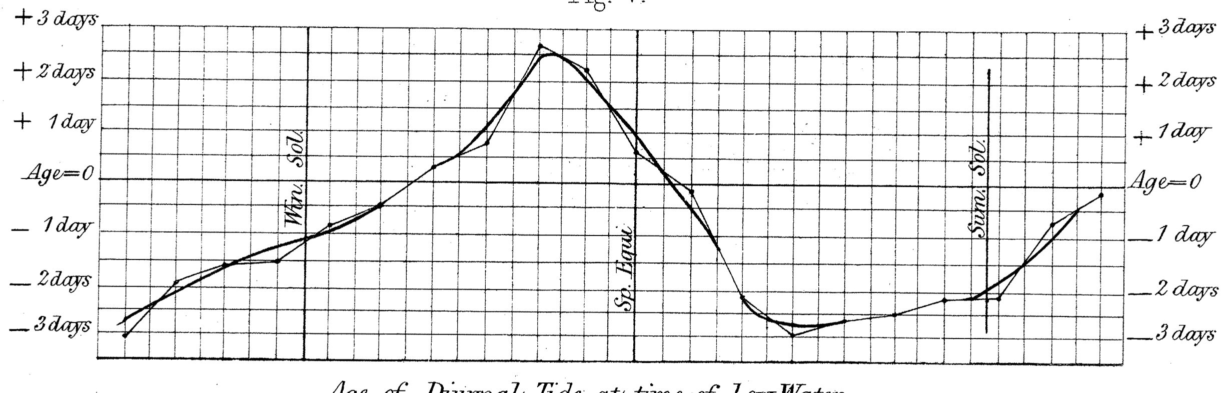
Interval of vanishing of Diurnal at High & Low Water.

Fig. IV.



Age of Diurnal Tide at time of High Water.

Fig. V.



Age of Diurnal Tide at time of Low Water.

J. Basire lith.

Diagram No. 1.

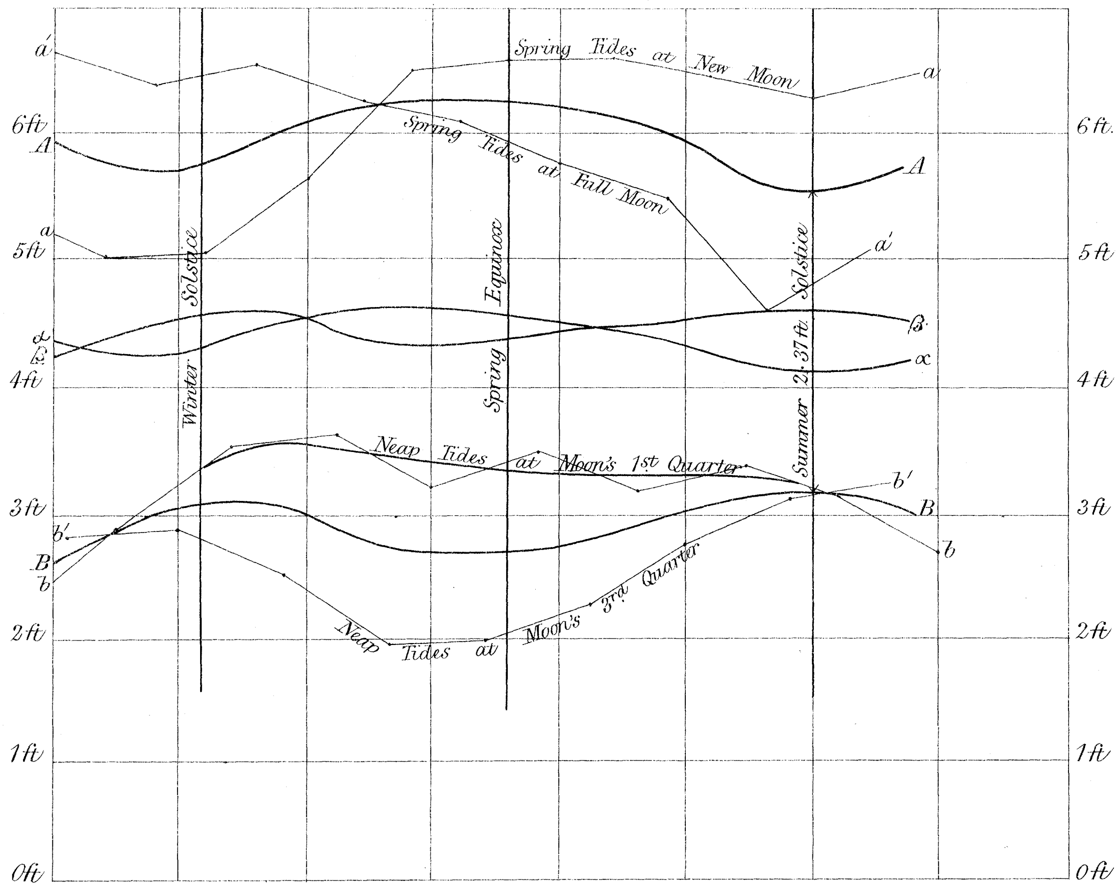
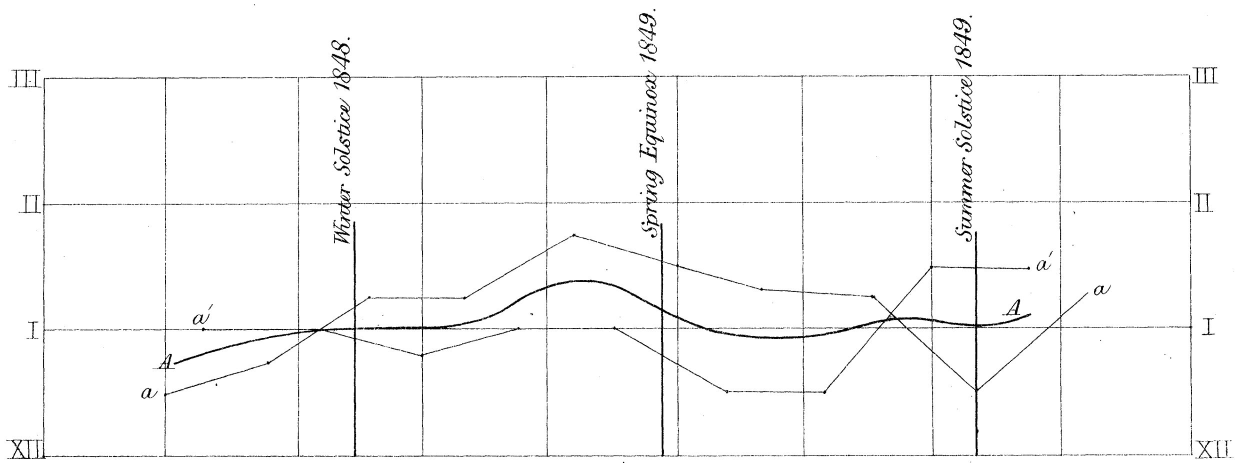


Diagram No. 2.



J. Basire lith.